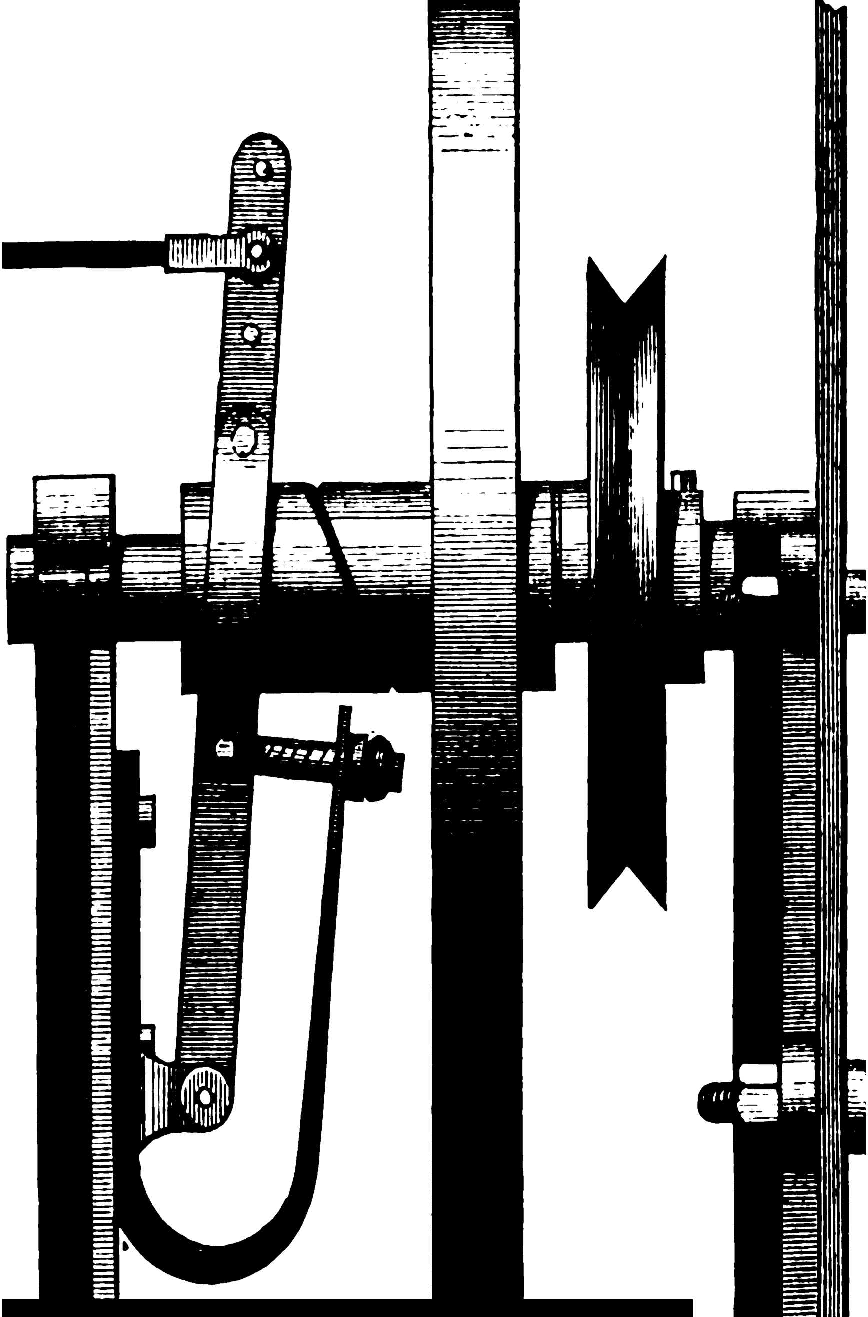

Journal

Society of Engineers (London, England)

SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

COMMITTEE AND OFFICERS FOR 1861.

J. AMOS, *Chairman.*

G. W. ALLAN, 1857.	*Past-Chairmen—Members ex officio.*
R. M. CHRISTIE, 1858.	
H. P. STEPHENSON, 1856 & 1859.	
R. M. ORDISH, 1860.	

W. T. CARRINGTON.	C. L. LIGHT.
C. CUBITT.	J. LOUCH.
J. LACEY.	E. RILEY.

A. WILLIAMS, *Hon. Secretary and Treasurer.*

W. H. LEFEUVRE, *Auditor.*

✓

Place of Meeting, Lower Hall, Exeter Hall, Strand.

MARCH, 1861.

pp. 15-16 missing
6-7-37 a

PREMIUMS.

At the Meeting of the Society, on January 14th, 1861, Premiums of Books were awarded to :—

Perry F. Nursey, for his paper "On Quartz Crushing Machinery."

And to

C. W. Stocker for his paper "On Diving Apparatus."

SOCIETY OF ENGINEERS.

RULES AND BYE-LAWS.

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Object of Society.

This Society was established for the discussion of scientific and other subjects of general interest.

The Election of Members.

1. The Society shall consist of members of only one class.

Mode of Election.

2. Members to be elected by ballot; one third black balls to exclude.

How to be Proposed.

3. Candidates for membership to be proposed by a member of the Society and recommended by at least three others; the proposer to forward these particulars to the Secretary at least seven days before any ordinary Meeting;

the ballot to take place at the conclusion of such Meeting.

Expulsion of Members

4. No member to be expelled without the consent of at least three fourths of the members present, or by proxy, at a Special General Meeting, called for such purpose.

Visitors.

5. Members to have the privilege of issuing cards of invitation for two visitors at each Ordinary Meeting.

Rules for the Election and Proceedings of Committee and Officers.

Mode of Election.

6. The officers of the Society to be elected at the General Meeting of the members in December, each year, by ballot.

Number of Officers.

7. The officers shall consist of a Committee of seven members, in addition to the Past Chairmen of Committees, and Honorary Secretary and Treasurer, who shall be members ex officio.

Election of Auditor.

8. A member (not being one of the Committee) to be elected as Auditor, who shall make his reports at the first Ordinary Meeting in each year.

Quorum.

9. Four members to be a quorum; the Chairman to have the casting vote.

Election of Chairman.

10. The Committee to elect their Chairman by ballot, who shall be Chairman of all Meetings throughout the year.

Nomination of Deputy-Chairman.

11. In the absence of the Chairman at any Meeting, a Deputy shall be nominated by the Committee.

Management of Funds.

12. The Committee shall have the sole management of the funds, and the entire superintendence of the Society.

Selection of Subject for Discussion.

13. The Committee shall select the subject and papers to be read and discussed at the Ordinary Meetings. Members wishing to read a paper, or who wish to have a particular subject discussed, must notify the same to the Committee.

Meeting of Committee.

14. A Special Meeting of the Committee shall be called on the requisition of three of its members.

Retirement of Committee.

15. The Committee to retire each year, but to be eligible for re-election.

List of New Officers.

16. The Committee resigning office shall prepare a list of proposed new officers, which shall be sent to each member with the notice of the General Meeting.

Members wishing to be Elected on Committee.

17. Any member offering himself for election on the Committee, must give in his name to the Committee on or before the ordinary meeting in November. The name of such member shall be appended to the list proposed by the Committee.

Election of Committee.

18. Members who do not attend the General Meeting should forward the above-named list to the Honorary Secretary, with such alteration in the names as they desire, which, with those from the members present, shall be handed to two scrutineers appointed

by the Chairman, who shall ascertain the number of votes obtained by each member; and the Chairman shall make known the result to the meeting.

Equality of Votes.

19. In case two or more members have the same number of votes, the election of such members to be decided by lot.

Election of Hon. Secretary and Treasurer.

20. The Honorary Secretary and Treasurer to be elected by the members of the Society, and to be nominated in the list of officers proposed by the Committee for the year ensuing.

Custody of Funds and Accounts.

21. The Honorary Secretary and Treasurer shall keep the funds and accounts of the Society, which shall be open for the inspection of any member.

SUBSCRIPTIONS, &c.

Entrance Fee

22. An entrance fee of ten shillings to be paid by members on election.

Annual Subscription.

23. The annual subscriptions to be ten shillings, and paid in advance. They are due on the first day of January in each year.

Members Joining.

24. Any member joining the Society shall pay his entrance fee, and annual subscription, which shall be considered as paid only to the 31st of December ensuing.

Disqualification to Vote.

25. Members whose subscriptions are in arrear for the previous year are not qualified to vote.

Subscriptions in arrear.

26. Members whose subscriptions are in arrear for three years, to be struck off the register of the Society.

Meetings of the Society.

Ordinary Meetings.

27. The ordinary meetings shall be held on the second Monday in January, and the first Monday in February, March, April, May, June, September, October, November, and December, unless otherwise specially ordered by the Committee. The Chair to be taken at 7 o'clock, p.m.

Special General Meeting.

28. A Special General Meeting of the Society shall be called on the requisition of eight

of its members, who shall send to the Committee the resolutions to be proposed by them at such meeting.

Management of Discussion.

29. The Chairman to have the power of directing the manner of discussion.

General Meeting.

30. There shall be a General Meeting held within the first fortnight of December in each year, to elect the officers of the Society for the ensuing year.

Voting by Proxy.

31. Members are entitled to vote by proxy.

Notice of Meetings.

32. The Honorary Secretary shall write to every member at least four days before each ordinary Meeting, naming the date of the same, the subject of the Paper, and by whom to be read; likewise the names of Candidates for Membership, and by whom proposed.

Order of Business.

33. The Honorary Secretary shall commence the proceedings of each meeting by reading the minutes of the one preceding, the abstract of the paper read, with notes of the discussion

at the previous meeting, and the names of the gentlemen proposed for election.

Premiums for Papers.

34. Premiums in Books, not exceeding the value of Six Pounds, will be given annually for the best Papers read during the previous year. The decision to be left to the Committee, who are disqualified from receiving premiums.

Publication of Papers.

35. After each Paper is read, the Committee are to decide whether it would be desirable to publish it, and, on obtaining the author's consent, are to arrange with the Editor of a Scientific Journal to publish the whole or part of the same.

Alteration of Rules.

36. No alteration to be made in the above Rules and Bye-Laws without the sanction of a Special Meeting called for such purpose.

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Elected.	
1858	C. D. Abel
1856	A. Aird
1856	C. Aird
1855	J. Aird
1860	J. P. Adkins
1854	G. W. Allan
1859	J. Allen
1857	J. Amos
1860	G. Anderson
1859	W. J. Arliss
1859	J. Ashdown
1860	J. Ashlin
1860	E. Aydon
1861	W. B. Backshell
1859	J. D. Baldry
1860	H. T. Balfour
1860	C. Barnard
1860	E. B. Barnard
1861	J. C. Bayley
1860	J. Beardmore
1860	W. Benbow
1854	W. Binns
1859	C. Botten
1859	J. Boys
1858	R. Brass
1859	E. W. Briscoe
1860	R. Broad
1854	G. Broaderick
1856	Lieut. Broaderick, R.N.
1859	J. B. Brown
1861	W. H. Browne
1858	A. G. Browning
1857	C. E. Browning
1859	F. W. Bryant
1860	W. Buckle
1856	C. Burn
1859	G. Bush
1854	D. Campbell
1860	G. Campion
1859	J. Carrick
1858	W. T. Carrington
1859	L. B. Chemin
1854	R. M. Christie
1860	J. G. Clarke
1861	F. J. Clowes
1859	F. Colyer
1860	H. Coombs
1855	C. Copland
1860	J. Copland
1858	C. Cousins
1858	J. A. Cowen
1860	W. G. Cox.
1859	C. Cubitt
1859	J. G. Davenport
1859	L. E. Davies
1858	J. Dewdney
1859	B. Donkin
1061	J. Donkin
1859	R. Dyson
1860	J. A. Eaton
1859	P. Edinger
1858	E. Edwards

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.
Continued.

Elected.		Elected.	
1860	E. J. Eliot	1859	C. Horsley
1858	J. Elliott	1859	J. Humphreys
1860	J. Evans	1860	J. T. Hurst
1860	C. Farrand	1859	J. Hutcheson
1858	F.W.Featherstonhaugh	1860	F. M. Hyam
1859	H. Finlay	1859	F. Ingham
1859	L. Flowers	1858	T. G. Iveson
1856	J. Forbes	1860	P. A. Jeffcock
1859	C. Gandon	1860	G. Johnstone
1860	T. Gandy	1858	A. R. Jones
1861	L. Golla	1860	C. Jones
1859	G. Gordon	1860	H. Jones
1859	J. Glynn	1860	J. Keddall
1859	F. B. Gray	1855	J. Keith
1854	J. W. Gray	1661	C. F. Kell
1861	H. Greaves	1859	B. D. Kershaw
1860	J. C. Grover	1859	J. T. Kershaw
1858	J. Hadley	1854	R. King
1860	G. Hall	1861	E. B. Kirton
1860	F. Hallett	1860	W. E. Kocks
1860	R. Harris	1858	J. Lacey
1855	G. Harrison	1859	R. Laing
1358	T. Hendry	1861	J. Laurie
1859	D. J. Henry	1858	W. H. LeFeuvre
1859	F. Herring	1858	E. J. Leonard
1860	E. H. Hilliar	1860	J. Leonard
1860	J. S. Hobbs	1856	C. J. Light
1859	J. Hogg	1859	C. L. Light
1861	G. E. Hollest	1860	F. Littlewood
1860	F. Hope	1859	G. Livesay
1860	F. F. Hope	1859	J. Lockwood

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.
Continued.

Elected.		Elected.	
1860	E. H. Long	1860	E. Pemell
1856	J. Louch	1859	D. Pigeon
1858	B. Martin	1859	B. L. F. Potts
1861	B. B. Marshall	1859	J. T. Potts
1860	M. G. Martinez	1861	J. E. Pringle
1860	W. G. McGeorge	1856	J. Quick, Jun.
1859	W. P. Miles	1860	H. Raincock
1859	G. Molesworth	1859	G. Rait
1858	E. H. Moore	1858	C. W. Ramie
1859	W. Moore	1859	F. C. Reynolds
1861	J. F. Morgan	1860	E. Riley
1860	F. Morris	1860	C. Robinson.
1859	W. Morris	1858	H. Robinson
1860	W. Morris	1859	R. A. Rumble
1856	W. T. Morrison	1858	J. W. Rumble
1857	F. R. Moultrie	1860	W. Rutt
1859	G. Muriel	1861	C. Sanderson
1861	G. B. Nethersole	1856	B. Schmidt
1860	J. Newton	1860	G. Shaw
1858	P. F. Nursey	1860	G. P. Shearwood
1860	J. H. Ohren	1854	G. Shillito
1856	M. Ohren	1860	D. Siebe
1861	E. Olander	1859	E. Simpson
1860	D. A. Onslow	1858	A. P. Sinnett
1859	T. Orchard	1859	A. B. Smith
1857	R. M. Ordish	1859	G. F. Smith
1856	T. Ormiston	1860	H. Smith
1959	J. B. Paddon	1860	H. G. Smith
1859	G. G. Page	1859	R. M. Smith
1859	H. R. Palmer	1858	S. Smith
1858	W. Parsey	1854	W. H. Smith

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.
Continued.

Elected.	
1858	W. Snell
1659	A. E. Stephenson
1854	H. P. Stephenson
1857	W. H. Stephenson
1859	C. W. Stocker
1860	A. Suari
1859	W. P. Sutherland
1861	L. Swann
1860	A. Thorn
1860	P. Thorn
1860	W. W. Tothill
1859	H. H. Treppas
1858	G. Waller
1861	A. E. Walton

Elected.	
1860	D. Watson
1861	S. Watson
1859	W. H. Webb
1859	E. J. Whitaker
1860	J. Willcock
1855	A. Williams
1860	A. Wilson
1860	C. G. Wilson
1861	G. Wilton
1858	F. Wise
1858	E. I. Woodhead
1861	A. F. Yarrow
1859	F. Young
1859	J. L. H. Young

Abstracts of the Papers read during the year 1860, at the Monthly Meetings of the Society of Engineers.

January 9th, 1860.

R. M. ORDISH in the Chair.

ON QUARTZ-CHRUSHING MACHINERY.

By Perry F. Nursey.

The author opened his paper by observing that the main object sought to be attained in reduction machines was the economical and effectual extraction of gold from its matrix, which, when not an alluvial deposit, was generally of a very hard and refractory nature. With this view, the machines were designed to act mechanically as pulverisers, and, by the introduction of mercury, chemically, as amalgamators. The two operations being effected in some simultaneously, in others by two distinct processes.

The subject was treated under the following heads:—First, the natures and properties of the substances to be acted upon by the machines were examined; secondly, the processes of reduction and amalgamation were described, and the requirements of an efficient machine pointed out; and, lastly, the machines themselves were considered, and explained by the aid of appropriate diagrams.

It was then stated that gold had been known from the earliest ages, and was by no means a *rare* metal, though not so universally diffused as those of a baser character. It did not readily combine with oxygen, and thus suffered but little diminution by the formation of an oxide. Gold had been kept in a state of fusion for eight months, without perceptible change. Its extraordinary malleability and ductility were noticed—leaf gold, which was only the 282,000th part of an inch in thickness, being instanced as an example of the first-named attribute, whilst the second was exemplified in the manufacture of gold thread, in which a cylinder of silver weighing 360 ozs. was coated with 6 ozs.

of leaf gold, drawn through holes so decreasing in diameter that a wire, thin as a hair, and 200 miles in length, was ultimately produced, the gold with which it was equally coated not exceeding the 500,000th part of an inch in thickness. Gold was found only in the metallic or native state, in mechanical combination with various substances, but occasionally alloyed by other metals. It occurred crystalised, having for its matrix vitreous quartz, generally known as rock crystal, a substance sometimes transparent and colourless, at others opaque and tinted by oxides or sulphates occurring in its vicinity. It was insoluble and infusible, about seven times harder than glass, and had a specific gravity of about 2·65.

Gold existed also in a matrix of a softer description, known as gossan, or red oxide of iron, the outcrop of copper and other mineral lodes, being itself a mineralised substance, occasionally intermixed with quartz, and bearing evidence of a volcanic action. It was upon this description of ore the author operated for gold in North Molton, Devon. Samples were laid on the table, as also were some prills of gold obtained therefrom.

Mercury was noticed as being of considerable importance in gold extraction. The chief peculiarities which marked this useful metal were its constantly fluid state, solidification being only effected by the most intense cold: it boils at 680 degrees, and having but slight affinity for oxygen, suffered little loss by repeated distillation, but under certain conditions, however, grey and red oxides were formed. The readiness with which it united with gold, and could be again separated therefrom was its most important feature in reference to the subject of the paper.

The principles of the process of gold extraction by chemico-mechanical means were then alluded to. The gold ore, roughly broken by hand-hammers or by stamps, was to be submitted to a machine for reduction to an impalpable powder, which process might be facilitated and amalgamation aided by previously calcining the ore, thus rendering it friable, and driving off its sulphurous and arsenical constituents. Assuming the two principles of reduction and amalgamation to be carried on at once, mercury would be placed in the machine in contact with the grinding parts, the gold being thus brought directly under its in-

fluence. The admission of water to the mill would assist the gravitation of metallic particles, and carry away the earthy matter through wire-gauze sieves, at a proper level. Care would have to be observed in regulating the working speed, high velocities disintegrating the mercury, and occasioning loss by transmutation.

The amalgam when formed would be either squeezed through a leather bag, and the richer parts which remained submitted to cupellation, or the whole of the mercury distilled over, and the gold extracted from the residue by the crucible. Of these two methods the author preferred the latter, as having many advantages over the former.

The conditions of an efficient machine appeared to be simplicity of general arrangement, strength of construction, directness and evenness of action, with a full, steady, graduated crushing and triturating power. The absence of all vibratory or hammering action was desirable, and its avoidance became imperative in machines where the two processes were combined. The sensitive nature of the mercury implied that reduction and amalgamation should be conducted separately.

The limits of a paper forbidding a notice of all the inventions for extracting gold, the author classified them with reference to the principles of their action, and gave an example of each class, selecting for the purpose those with which he had been practically acquainted, and others prominent either for their public notoriety or for their apparent merits. With a view of tracing its development, the author proposed to treat the subject in chronological order.

A grant of Charles I., in 1630, to one David Ramseye, appeared to be the first systematic attempt to place the question on a commercial basis, in civilised times. The Crown granted Ramseye very large powers, without requiring him to specify the means he would adopt to extract gold, and summary punishment awaited any one infringing on Ramseye's privileges. The author noticed the improvements in the patent law since the time of Charles, observing that further amendment seemed necessary, from the fact that tribunals, established to adjudicate upon widely different questions, were frequently compelled to waste public time and money in the most elaborate, and often the most fruitless, scientific disquisitions.

Fifty-seven years after Ramseye, Messrs. Clarke and Brent patented

"Ways and means never before known for extracting gold." What these ways were is left to conjecture.

In 1773, John Barber proposed to utilise air, fire, and water to the same purpose, definitely describing a complication of machinery, the working of which did not appear to have been publicly recorded.

Proceeding to more practical appliances, Thomas's mill, constructed in 1777, was noticed. An edge runner, accompanied by rakes, or stirrers, and spring sieves, was made to grind the ore by horse-power, in a circular trough, and had nothing but its simplicity to recommend it.

The Baron de Chastel appeared to have been the first who practically considered the question, which resulted in the production of machinery in 1783, which might be considered the prototype of all subsequent inventions, subject only to collateral modifications. Here four mills were used, in which the gold ores were separately reduced and amalgamated, extensive apparatus for the purpose of carrying out the detail operations being attached, leather bags and cupellation of the amalgam concluding the extraction. The author was not aware of the adoption of this system in England, although the baron made extensive researches therewith at Geneva. The demerits of De Chastel's apparatus existed mainly in its mechanical deficencies.

No advance was made for more than sixty years, until, in 1849, Alfred Newton calcined the ore, and reduced it by graduated rollers.

In 1850 Crosskill's eccentric mill was used successfully as a crusher, and the "Council great medal" was awarded it in 1851, but from its liability to get out of order it afterwards fell into disuse. The discovery of vast gold fields in Australia and California, and of auriferous deposits in Great Britain about this time, gave an impetus to invention, and the production of "gold machines" rapidly increased.

Isham Baggs embodied the principle of the steam-hammer in his "stamps," which were of great power, and came very generally into use at the time of their introduction, a 4-horse engine crushing from 15 to 20 tons of ore per day, amalgamation being separately performed. These steam-stamps continued to be used abroad with success.

"Cochran's Quartz Crusher" was the application of balls rotating be tween circular grooved tables. The author had examined one of these-

machines, and from the weight of metal, high working speed, and incomplete mechanical detail, he had formed an adverse opinion upon it, and conld not instance its adoption beyond experiment.

Richards and Groves's Mill was at one time thought favourably of; but the liability of the peripheries of the grinders to be thrown out of concentricity appeared a fatal objection-

Shrapnel's method of reducing gold ores, by discharging them from a piece of artillery against a concave target, was noticed as one of the many schemes, more distinguished for originality than utility, which then abounded.

Capt. Moorsom's arrangements at the Britannia Mine, North Molton, Devon, with which the author was connected, consisted of heavy edge runners, accompanied by scrapers, and working in pairs; they ground and amalgamated the ore, previously calcined in pans. Gold extraction proceeding but slowly, barrel amalgamation was substituted, the ore being ground dry in the mills, which worked very effectually, reducing the gossan to an impalpable powder, some of which was exhibited on the table. This arrangement was superseded in 1853 by Perkes's machine, a cast-iron pan, 6 ft. diameter and 3 ft. 6 in. high, in which five heavy cast-iron cones revolved, worked by a central vertical shaft. Numerous working trials were made, and among others, the author gave the details of one conducted by him upon fifty tons of auriferous gossan. The time occupied in reduction and amalgamation was four weeks of day and night work, and the final results were a loss, by disintegration, of 50 per cent. of the mercury employed, and an ultimate yield of 1½ ozs. of gold or 14 grains per ton of ore. Every attempt to extract gold from North Devon ores remuneratively by this machine proved a failure. Its arrangement theoretically implied an approximation to perfection as a crusher, but practice determined its inefficiency.

The system of spheres rotating in revolving basins, patented by Berdan, obtained great notoriety in 1853-4. The basins were 7 ft. in diameter, and the balls of which (there were two to each basin) weighed respectively one and two tons each. The success of these machines in gold extraction was unparalleled. They were to crush and amalgamate ten tons per basin per day of twelve hours; but the author's experience of their work in two separate trials, under very favourable conditions,

was one ton in two hours and a half, or equal to 4·80 tons per day. Some experiments conducted by Professor Ansted, and reported by him to the Society of Arts, gave more favourable results; but the spiral motion claimed for the large ball upon analysis appeared wanting, inasmuch as the smaller ball, by occasional contact, could not alter the course of one twice its own weight, but being itself struck at a point out of its centre, it received a motion additional to that around its horizontal axis, which was of no practical benefit, as all the work was done by the large ball. The author was informed that a committee of gentlemen from New York had been recently examining witnesses in London in reference to Berdau's machine, but the proceedings had been conducted with closed doors, and the object of the inquiry had not transpired.

Pym's crushing mills were six-edge runners, loosely hung on a horizontal fixed shaft, their edges running in a series of troughs, cast on revolving conical bed plates, and embodied a principle that with further development might prove useful.

The pestle and mortar, as adapted by Moss, formed a very primitive crusher, which was subsequently improved upon, but at its best it appeared ill-calculated to succeed as a reduction machine.

Dr. Collyer, of New York, carefully considered the question of gold extraction, and his invention of 1853 met most of its requirements. He reduced the ore in separate chambers by a graduating power, with an excellent triturating action, and amalgamated in mercury baths, through which the powdered ore was drawn by fluted rollers. A machine was erected at Ipswich, and upon repeated trials proved very successful. The mechanical detail of the apparatus is deficient, but independently of this it appeared more nearly to approach the fulfilment of the conditions of a perfect machine, as advanced in the early part of the paper, than any that had hitherto been noticed.

Mr. Mitchell, the chemical analyst, and author of several scientific papers, had reduced the principles of gold extraction to very efficient practice by the introduction of conical friction rollers between spheres rotating in an annular trough; the contact of the conical with the spherical surfaces communicating to the latter a rotatory motion on a vertical, in addition to that round a horizontal axis. The ore was im-

palpably reduced in the mill, and carried through twelve amalgamators, each furnished with two revolving screws. The multiplication of the lengths and revolutions of these screws clearly showed that the ore in its passage from the machine to the exit point of the last amalgamator traversed in the space of one hour the incredible distance of nearly eleven miles, within the compass of an amalgamating-house 30 feet in length. Mitchell's apparatus was now coming into considerable use in South America, where the increase in the yield of gold is from 250 to 300 per cent. in its favour upon the methods previously adopted.

The paper concluded by noticing the results of some interesting experiments, and a working model of the machine and amalgamators was exhibited.

DISCUSSION.

Mr. Amos said he had listened with very great interest to the paper, and that much valuable information had been elicited, but thought there was still much to be learnt on this subject. He considered that, in most of the apparatus described, too much was attempted to be done by one machine. For example, crushing, grinding, washing, and amalgamating in several cases, had to be done in one implement; this occasioned many objectionable features in their construction, as the constant working of metal against metal being exposed to the grit in water, would naturally greatly affect the wear and tear of the machine. Again, in Berdan's machine, heat was applied beneath, and above a constant stream of water was running through, which of course greatly neutralised the effect.

He thought it would be far better to divide the operation thus:—first, wash or calcine the ore; secondly, subject them to the action of the stampers; thirdly, crush them by edge runners, and then wash them in a separate machine designed exclusively for the purpose.

Mr. Clay considered that grinding the ore by rollers reduced the size of the quartz with less waste than stampers.

The capabilities of the various machines were discussed by Messrs. Richards, Edwards, Smith, and others.

Mr. Nursey, in answer to a question from Mr. H. P. Stephenson, stated that the yield of gold per ton of ore that would be remunerative

depended on many circumstances, but the average might be taken at four-dwts. under ordinary conditions.

The Chairman, in summing up, agreed with Mr. Amos, that too much was attempted to be done in one machine; and, after reviewing the various machines, he gave the preference to Berdan's for grinding, and Mitchell's for amalgamating.

February 6th, 1860.

R. M. CHRISTIE IN THE CHAIR.

ON WOODEN JETTIES ON THE RIVER THAMES, AND THEIR IMPROVEMENT OF THE INSHORE NAVIGATION.

By JOHN G. DAVENPORT.

The condition of the Thames, and the improvements thereon, will always be a matter of great interest to the people at large. The progress of civilisation of a people is shown by the condition of their roads, railways, and canals; and again by the facilities which are afforded to the shipping by means of piers, landing-stages, or jetties, on the various rivers. This paper refers more particularly to jetties on the river Thames, and tends to show that, while in nearly all branches of engineering science great progress has been made, this question, with regard to the Thames, has been much neglected. A contrast is drawn between the ports of Liverpool and London, in respect of landing-stages lately erected at the former place. The increase to shipping by the introduction of steam within the last forty years has made it necessary to adopt more improved forms of landing-stages than exist at present in many places on the river Thames. The substitution of wooden jetties in place of "dummies" or decked barges, as heretofore, tends very much to carry out this improvement, and offers increased facilities for inshore navigation. The new Board of Conservators are taking the necessary steps to improve the landing-stages under their immediate control, and are allowing proprietors of wharfs below bridge to adopt jetties that are found do not interfere with the navigation. A diagram was submitted to the meeting of a wooden jetty, constructed by T. M. Gladstone and Co., at Free Trade Wharf, and which has been found to answer its requirements to the fullest extent. This jetty was designed by Mr. Davison, C. E., and extends into the stream 80 ft., having two

openings, one of 24 ft., and the outer one of 55 ft. There are two piers supporting the whole, composed of 28 creosoted piles, and driven into the bed of the river from 10 ft. to 12 ft. The width over all of the jetty is 24 ft. The outer opening of the jetty is composed of two arched ribs, which support the platform and movable gangway. This movable gangway is 35 ft. long and 8 ft. wide, one end of which can be lowered to suit nearly any height of the tide, being provided with balance-weights and winch power, so that one man can raise or lower it in a few minutes. A comparison was drawn between the advisability of adopting wood in preference to iron in these structures, the cost of wood being considered at least one-third cheaper. It was then shown that, by the general adoption of jetties similar to this, or of an improved form, in substitution for "dummies," the inshore navigation will be considerably improved, seeing that barges, and all other small craft, can pass underneath the jetty and near to the quay.

DISCUSSION.

Mr. Ormiston considered the jetty mentioned by the reader was not any improvement on the dummy system, and thought that the wooden piles used would not last more than twenty years, and even if creosoted would be attacked by the worm. He advocated the use of iron for such structures, feeling sure that its extra cost would be counterbalanced by its greater durability.

Mr. Glynn did not think the piles would be affected by the worm, as it did not attack timber in fresh water. He then mentioned a plan of keeping timber piles constantly soaked with creosote, by boring a hole down the centre of the pile, and keeping it filled with creosote as often as it was required. He preferred iron to wood for jetties, and did not consider the plan of Mr. Davenport so good as that adopted at Paul's Wharf, Blackfriars Bridge, &c.

Mr. H. P. Stephenson thought the slope of the movable part of the jetty, when at its lowest point, would be too great to render it useful for the purposes for which it was designed.

Mr. Gladstone stated that the piles used in the jetty, noticed in the paper, were driven 10 ft. to 12 ft. into very hard gravel, with a monkey of 15 cwt., with a fall of 15 ft. He stated the cost of the jetty to be 1000 guineas.

Mr. Bryant stated that, in an experiment at the New Westminster Bridge, piles were driven 15 ft. into the clay, with a weight of 25 cwt., and a fall of 6 ft., and bore a weight of twenty tons on each pile without any sign of sinking.

The question of the movable platform was discussed by Messrs. Nursey, Allan, and Kershaw, who thought the slope would prove too great for any ordinary traffic.

Mr. Davenport, in answer to the objections raised to the movable platform, stated that it was very easy of adjustment to suit the various heights of the tide, and that the slope had not yet proved too great for the landing either of passengers or cattle.

The Chairman, in summing up, advocated the use of iron in preference to wood; but stated that he thought, if wood was used, it should be well creosoted.

March 5th, 1860.

R. M. CHRISTIE IN THE CHAIR.

LOCKS AND FASTENINGS.

BY W. P. MILES.

The lecturer, after stating the difficulty under which he felt himself to labour, by reason of the indifference with which the subject is generally viewed, that notwithstanding the important part it played in the comfort or discomfort of domestic life, there were few who cared to take the trouble to make themselves acquainted even with its elements, though so easily now-a-days attained. Insomuch that, with a vast number of persons, the "click" is considered a proof of excellence, though he need scarcely point out that it was a sign of a frictional wear and tear denoting a source of self-destruction, it is also well understood by those who retail locks that, generally speaking, the key sells the lock, showing no thought is given that the fancied internal arrangements, which a much cut about key leads to the idea of, are mostly wholly wanting, and are also useless.

Referring then to the diagrams, he drew attention to the mode of construction of locks from the earliest times to the present day, pointing out the excellent character of the arrangements of the ancient

Egyptian lock, which might be traced through the East to some parts of Turkey, &c., even now.

He further proceeded to show how false were the notions of the security of warded locks which, by a glance at the diagram, was at once apparent. He also gave a brief resume of the celebrated Lock Controversy, during the time of the Great Exhibition of 1851, between that scientific lock picker, Mr. Hobbs, and the greatest lock makers of the day, and introduced to notice the extremely clever instrument which has proved the "open sesame" of those locks whose security had hitherto a world-wide fame, and which led to such lengthened discussions, and even leaders in the leviathan *Times*, converting a whole army of clerks and others into lock pickers, and controversialists, leading to many new patents, and giving an insight to the public how wholly at variance with known laws is the system of wards in locks, and their total insecurity because of the easy means by which they are evaded, facts especially needed to be known, to enable them to cope with the professed plunderers to whom the possession of such knowledge formed a part of their discreditable education.

He further drew attention to the principles of his own Patent Marine Lock, so named from the peculiarity of its construction, enabling it to be made wholly of anti-corrosive materials, and consequently rendering it peculiarly adapted for damp, or exposed situations, and for marine purposes. In explanation, he showed it to be eminently an anti-frictional lock and that it could not be picked by Hobbs' system of pressure on the bolt, by taking off the cap, thereby fully exposing the internal parts, applying all the power of the hand, with a thin penknife, trying all the lifts, and though all the levers were exposed to view (holding it well up in his hand that all might see), he could not pick it; he then handed it for others to try, and notwithstanding the presence of Mr. Hobbs himself, it remained unpicked.

DISCUSSION.

Mr. Glynn wished to know the composition of the metal in the springs of Mr. Miles' "Marine Locks," and how the spring was produced, as he could not imagine it would last.

Mr. Young could not see how the Egyptian lock worked. There is a

lock now in common use for barns, pigsties, &c., possessing the advantage over the Egyptian lock, of not requiring a key; with regard to springs he thought with Mr. Glynn, that brass would not answer, so well as good steel.

Mr. Hobbs said that Mr. Miles' lock simply contained a spring cut out of the lever, and although he was quite aware that, in some cases, steel springs were liable to rust, yet, under any circumstances, they would last much longer than brass springs. He had found that the worst metal that could be chosen for a lock spring was brass. The public were quite mistaken in supposing that lever locks belonged to Chubb, because, in 1709, a lock was patented which contained a double tumbler; the only peculiarity in Chubb's lock was a detector. Mr. Hobbs then described how he should pick warded locks; and that the principle of Bramah's lock was absolutely the same as any ordinary lever lock, with the same principle of action that regulated tumbler locks: the public had quite a wrong impression as to their security. Here he fully described how he picked Bramah's lock, and won the 200 guineas reward, and operated on Chubb's lock at the Great Exhibition of 1851, simply to show the principle upon which it was picked He most strongly disputed the excellence of the spring of the lock referred to by Mr. Miles, and also the impossibility of picking it.

Mr. Parsey, in proof of the durability of brass springs, instanced a case of a clock which had gone well for eight or nine years.

Mr. Hobbs would always prefer steel springs; in exposed situations, brass springs were quite as likely to become corroded.

Mr. Nursey exhibited a lock which was patented by Mr. Collett in 1845.

Mr. Hobbs thought the lock shown by Mr. Nursey was, as it were, a lock within a lock, in fact, something like that known as the "dial lock," of which he had picked several: the principle was by no means new or effective.

Mr. Miles, in reply to the opinions adduced, said, with regard to the new lock which he had brought before the meeting, the chief objection appeared to be its spring, to which he had given great attention, and his experience told him that springs made of brass, or any similar mixture of metal, were, as to time, wear, or tension, as effective as

steel; the spring in his lock was at rest without any tension until the key lifted it, and then the tension was very slight; he had tested these springs, and found forty-eight hours' tension had no effect on the power or elasticity. It was quite possible, if inferior metal were used, the same result might not be gained. He certainly could not agree with Mr. Hobbs, that brass springs in exposed situations were not equal to steel, his opinion being that upon his principle they were infinitely superior for any kind of lock.

The Chairman said, the discussion had so fully entered into the subject that there was nothing left for him to say. Mr. Miles had read an interesting paper, and the meeting had been favoured with the presence of Mr. Hobbs, to whom he was quite sure all had listened with much pleasure.

April 2nd, 1860.

R. M. ORDISH IN THE CHAIR.

ON THE MACHINERY EMPLOYED IN RAISING WATER FROM AN ARTESIAN WELL.

By W. Morris.

The author described the machinery now used for raising a large supply of water from a well sunk to a depth of 300 ft in chalk by the Kent Waterworks Company at Debtford.

Having given the particulars of the well and bore-hole, he, stated that the steam engine employed was a modification of the single-acting Cornish engine, in which, by fixing the beam under the cylinder, and working the piston rod through the cylinder bottom, the centre of gravity was brought close to the foundation, and the house built was smaller and much less expensive than is usually the case.

The diameter of the cylinder was 30 in. and the stroke 7 ft.; the steam lifted a counter-weight attached to the inner end of the beam, which, in descending, raised the water from the well by means of a lifting pump 26 in. in diameter, connected to the outer end of the beam. The author thought that by this arrangement the engine worked more expansively than it would have done had the water been lifted by the direct pressure of the steam.

The parallel motion attached to the pump-rod was explained: it being the first application of a novel piece of mechanism, requiring no fixed anchorage, the radius-rod being connected with the beam. An oscillating stuffing-box was also described, which reduced the friction, and prevented the vibration of the pump-rods (arising from their length) affecting the steadiness of the pump.

The boiler was 5 ft. 9 in. in diameter by 28 ft. long, and made entirely of ¼-inch steel plates; it worked well with a pressure of 35 lb. per square inch, but the author considered that the lightness of the material would be found more advantageous for locomotives and marine boilers.

The machinery, which was made by Messrs. Harvey and Co., of Hayle, Cornwall, from their own designs, in accordance with the requirements of the company's engineer, has been working satisfactorily for three years, raising 2,000,000 gallons of water per diem 43 ft. high, with a consumption of 18 cwt. of small screenings of house coal for twenty-four hours.

The author, in conclusion, stated that he did not bring forward this example as a model engine for general purposes, but as an arrangement which met the requirements of the case with economy and efficiency.

DISCUSSION.

Mr. Buckle thought the subject was of the greatest importance when they considered the health of towns and cities. The Egyptians treated the hydraulic engineer with the highest respect, knowing that the welfare of their own country entirely depended upon the hydraulic operations. When they looked at the well at Cairo, called "Joseph's Well," which is a rare work of art, 300 ft. deep and worked with cattle at the present time; it seemed strange that they do not take a copy from us and make use of steam. Amongst the remains of Babylon could be discerned its buckets, or earthen pots fixed to chains or straps, by which water was lifted from the Euphrates some 200 or 300 feet.

Mr. Morris, in answer to Mr. Gray, said the well, from which his engine pumped, was sunk at Deptford about three years since, and in answer to other questions, stated that the water was lifted into a tank

and that it was not a distributing, but merely a lifting engine that was employed.

Mr. Gray wished to know if that description of engine could be recommended for all purposes of similar work; and with regard to the steel boiler, it was described as having several rings round the steel-tube, he would like to know if any such rings were used in the Cornish boilers.

Mr. Glynn understood Mr. Morris to say that if they pumped too fast they had lumps of chalk in the well which went down the borehole. He (Mr. Glynn) had never seen cylinders driven so loosely as to admit lumps of chalk. With regard to the oscillating stuffing-box he thought all requirements would have been met by having guides in the pipe. He (Mr. Glynn) thought it would be interesting to the meeting to know the cost of raising the water to the respective companies At the East London Water Works the cost of raising one million gallons 100 feet was 18s. 1d. including the whole of the working expenses.

At Green Lane Water-works .	£0	15	9	per mill. gals.	100 ft. high.
At Lambeth Water-works . .	1	15	0	„	„
At Old Southwark Water-works	0	12	0	„	„
At Grand Junction Water-works	1	15	0	„	„

Mr. Carrington said it appeared to him that the pump-rod worked the parallel motion: he could not see how the friction of the rods, &c., could be overcome otherwise than by the pump-rod; this action would account for the vibration of the pump-rod.

Mr. Parsey thought the engine should be kept as low as possible, to prevent vibration, and he saw no objection to support the cylinder on cast iron girders; there was certainly a waste of power in moving the balance weight, but taking the engine altogether it answered its purpose admirably.

Mr. Young objected to steel boilers, and suspended pumps.

Mr. Horseley contended that hanging pumps were most convenient, to lift out in case of accidents.

Mr. Morris, sen., thought the objections raised arose from misapprehension. He would like to know how pumps could be securely fixed in a well where the water rose from bottom to top in a few minutes.

Mr. Young said divers could go down—they can go down twenty-two fathoms.

Mr. Morris thought that it was probably his fault that so many misapprehensions had arisen, through his not having been sufficiently clear. With regard to the steel boiler, he was perfectly satisfied with it, it stood well, with the exception of the plates next the fire, where unequal expansion took place between the tube and the rings of angle iron which stiffen it; these plates have been replaced by half-inch Lowmoor iron. He had found it very convenient to have the pumps suspended, for he had occasion to pull them entirely out of the well several times. In answer to Mr. Gray, he replied that the duties of many engines are still reported in Cornwall.

The Chairman said that he thought the oscillation mentioned was attributable in a great measure to the parallel motion, and that an arrangement of levers to move the balance weight along the beam, according to the height of the water, would be advantageous to the economical working of the engine.

May 7th, 1860.

R. M. ORDISH IN THE CHAIR.

ON DIVING APPARATUS,

BY CHARLES WILLIAM STOCKER.

The author first drew attention to the importance of diving operations in the various branches of commerce to which they had been applied, and then proceeded to point out their usefulness as regards engineering practice, both in the construction and maintenance of our bridges, harbours, and almost all submerged works; and also in repairing vessels, more especially screw steamships, remarking that a diver, with a helmet and dress on, might frequently, in the water, repair the leak which all the efforts of those on board have failed to subdue, and thus save both life and property, for which reason he considered that vessels of large size and great value ought always to be provided with this apparatus.

The next points considered were the phenomena connected with respiration as the only correct way of arriving at a scientific conclusion

with regard to the supply of air to divers. After a comprehensive view of respiration and its effects on the air breathed, the reasons why the respired air contained carbonic acid while it had lost a considerable portion of oxygen were explained. The author afterwards considered the possibility of rendering the respired air fit to breathe without supplying atmospheric air. The alteration in a body of air by one man's breathing in it for an hour is stated by physiologists (as the mean of a large number of experiments) to be the addition of 1,332 in. of carbonic acid, and the loss of about the same quantity of oxygen, the nitrogen remaining unchanged.

This alteration he proposed to counteract by exposing a considerable surface of potash or some such substance, which having a chemical affinity for carbonic acid would absorb it as soon as they came in contact, and by supplying the quantity of oxygen destroyed. This subject was considered at some length, and it was proved that 7 oz. of hydrate of potash and 1 foot of oxygen per hour for each man would be sufficient. That with this supply animal life might be maintained had been proved by many experiments, and the author urged its application to submarine boats for two reasons—1. That the atmospheric air hitherto taken down in submarine boats contained 80 per cent. of nitrogen, which was not required for breathing, because the nitrogen sent down in the vessel had not been altered by respiration, and was therefore fit to be breathed again. Thus, by sending down oxygen instead of air the chamber would only need to be one-fifth the size, or else the divers might remain submerged five times as long. 2nd. That the proposed method would maintain the gases in their proper proportion, so that that of the nitrogen should not (by the destruction of oxygen) increase, as it always must when atmospheric air is added.

The diving-bells used by Dr. Halley and Smeaton were described, and particular attention was drawn to the apparatus used by the latter gentleman when repairing the bridge at Hexham, in Northumberland, for he then introduced diving to engineering practice; indeed, the addition of air-pumps to diving apparatus by Smeaton first rendered it practically useful for that purpose. Rennie used the bell extensively, and amongst many other places he applied it at Ramsgate Harbour with great success. The whole of the apparatus, suspending tackle,

bell, and also the method of fixing the stones applied there were described, and this description of bell is the one still generally used. M. Cave's modification of the diving-bell, Sautter's diving-bell, and the Nautilus diving apparatus were described and illustrated. By Sautter's arrangements, communication was maintained between the divers and the surface by tubes, large enough to admit the passage of a man, the tubes being furnished with two transverse air-tight partitions, so as only to allow a certain quantity of compressed air to escape. The weight of this bell was regulated by the proportions of air and water in an external chamber.

The Nautilus machine, when worked under favourable circumstances, was stated to be able to perform infinitely more work than any diving-bell hitherto invented, and it possesses the following advantages:—It is independent of suspension, and it has the power of sinking itself, or, on the other hand, of raising heavy weights—this power being entirely dependent on the relative proportions of water and air in the chambers surrounding the bell. The air is supplied from a receiver at the surface, in which it is compressed to a greater density than the water at the greater depth the Nautilus has to descend. Deschamps and Wilcocq's free diving-boat was also alluded to and illustrated.

The diving-helmet and dress, and the whole apparatus, including pumps, hose, &c. &c., were explained and illustrated. The forms used by Deane and Bethell were described. The latter gentleman, in 1835, introduced the closed helmet, which, in a great measure, superseded the open helmet previously used; Mr. Siebe made great improvements, and it is his arrangement, either with or without slight alterations, that is now generally used. Mr. Heinke's arrangement was described and illustrated.

Several improvements on this apparatus were suggested, one of which was that a pressure-gauge (applied in a simple form, and not with the complicated arrangements hitherto used) should always be connected to the air-chamber of the pumps, or the hose leading from it to the diver, by a piece of hose, the gauge being placed in such a position that the pumpers must see it. This, it was urged, would greatly add to the convenience of the diver, while it increased his safety; for a regular continuous supply of air might be maintained at any pressure he

required, while, should any sudden accident happen which would deprive him of all power of communicating by the signal line, the gauge would be nearly certain to warn the pumpers that something was wrong below. A consideration of the accidents which had occurred of late years would, it was maintained, show the usefulness of this improvement, and the superiority of this arrangement over any by which the diver could himself alter and regulate his own supply of air.

Before concluding the author alluded to the operations for raising the ships sunk by the Russians in the Harbour of Sebastopol during the Crimean war.

DISCUSSION.

Mr. Heinke, in opening the discussion, contended that the diving-bell and apparatus generally (which was on his plan) employed at Westminster Bridge, was both simple and effective. The valve, which was in construction a double-action valve, had one great advantage, viz., that at great depths, by being partially closed, it allowed the dress of the diver to become somewhat inflated, and thus, to a certain extent, relieved him of a considerable pressure; it was as simple as an ordinary cock, and could be regulated by the diver at pleasure; it further did away with the necessity of a gauge. A second valve at the back of the helmet enabled the diver to stoop while working merely by closing the first. He concluded by stating that four years constant use proved the excellence of the apparatus.

The Honorary Secretary then read an extract from a pamphlet on diving apparatus by Mr. S. Barnett, in which he claimed the principle of making the eye-piece to work with a hinge on an India rubber locking-piece, instead of with a screw and leather collar in the ordinary way, which principle both Mr. Stocker and Mr. Heinke concluded was not new, as they had known of its application, the one for two years, the other as long ago as fifteen years.

Mr. Siebe remarked that the principle of their (the Messrs. Siebe's) apparatus had been copied more or less by all manufacturers. He considered that the open helmet was in favour with divers (Whitstable ones particularly), because it required some dexterity in its use; but he gave the preference to the closed helmet on account of its being workable in nearly all weathers. He further mentioned the first appli-

cation of the guage at the Royal George in 1844, and entered at some length into the merits and demerits of the plans of revivifying the air and the Nautilus machine. He concluded by remarking that, even if the glass of a common helmet was broken, the air-pump, if good, would still give sufficient air to enable the man to be saved.

Mr. Barnett considered that the complicated construction of the old-fashioned guages was the great obstacle to their use.

Mr. Ormiston remarked on the economy, in most cases, of bells as compared with helmets, and quite concurred with the author of the paper in recommending the use of three pumps instead of two, as the supply of air would be much more regular.

Mr. Smith thought a good submarine light would be of great use to the diver; for example, a reservoir of compressed gas acting on a piece of lime like a sort of lime light; he had used a light of this kind for fishing purposes with success.

Mr. Amos remarked upon a means of communicating signals by a slate and pencil which he had seen at Dover, and also on the compressed air system as applied to bridge work, as at the Nile and elsewhere.

THE ADJOURNED DISCUSSION.

Mr. Young thought highly of the submarine light, but condemned the revivifying principle.

Mr. Carrack advocated in all cases the use of the guage.

Mr. Bryant thought that Mr. Heinke's valve had one important advantage, as it gave the diver the power both of ascending and descending to a certain extent. This Mr. Harrison could not precisely comprehend. Mr. Heinke explained the point, which, however, some members still thought was open to great doubt.

The author, in replying, explained the mode of application of the guage, and the reasons which prevented its successful use under water, concluding by a short comparison of the advantages and disadvantages of the several methods of producing light, and their application to submarine purposes.

After a few concluding remarks from the Chair the meeting separated.

June 4th, 1860.

R. M. CHRISTIE IN THE CHAIR.

ON GAS-METERS AND PRESSURE GAUGES

By J. WILLCOCK.

The author began by remarking upon the dismal and wretched appearance of towns lighted by oil-lamps, contrasting very favourably illumination by coal-gas. After stating the great importance of the manufacture and distribution of coal-gas, as it involves so much capital, he proceeded to make comparisons between several gas-meters, commencing with the original one invented by Mr. Clegg, in 1815. The remarks were strictly confined to wet gas-meters, deeming the subject too extensive to include dry-meters in the same paper,

The imperfections in the measuring drum or wheel invented by Mr. Clegg were stated to be chiefly in the use of a stuffing-box, which connected the inlet-pipe to the hollow shaft of the wheel, as it caused a great deal of friction, and consequently required a considerable pressure of gas to work it; but as being the foundation of the instrument at present in use, he considered Mr. Clegg's invention very ingenious, and that, wth a few modifications, it might have been of considerable service at the date of its introduction, and certainly much preferable to the system then carried on by the gas companies of making contracts at so much per burner. The measuring-drum or wheel of Mr. Malam's was next described, in which the whole of the valves, springs, and stuffing-box used in Mr. Clegg's meter are dispensed with, and consequently greater security could be reposed in its measurement; a modification of this wheel being used to the present day in large station meters. Mr. Crossley's wheel was then commented upon, and also the improvements by the late Mr. Wright, by which the measurement can be effected with the loss of less than one-tenth of an inch pressure. The author then proceeded to state that although the measuring-drum was the chief feature in a gas-meter, yet it was not all that was necessary in an instrument of this description when it was considered that, when once placed and put in working order, the majority of consumers rarely bestowed a thought upon it until his attention was called thereto, by sudden darkness, and also that it was necessary to foil the endea-

vours of dishonest consumers to steal unmeasured gas. An ordinary consumers' meter was then described, with all the extra appliances for the above-mentioned purposes. The faults in these meters were stated to be, that, as the measurement is effected by the aid of water, and, consequently, the measuring-chambers bounded on one side by water, it follows that the measurement would vary according to the height of the water-line; and as the index always indicated tho amount of gas that would have been passed through if the watar had been at the true level, the registration would, therefore, if the level was above or below, be false. Mr. Edge's meter was given as an instrument which avoided some of these defects, the syphon-pipe being cut down to the level of the true water-line; therefore the water-line could not be raised, any overplus water overflowing into a waste water-box beneath provided for that purpose.

To maintain a true water-line in gas-meters, or to compensate for the evaporation of the water, many ingenious contrivances had been invented. The first plan was by means of the bird-fountain, which was brought to considerable perfection by Mr. Esson, and latterly by Mr. Allan. One of the neatest and prettiest modes adopted was one introduced by Mr. Sanders, of Dublin, which is by means of a semicircular float, supported at the middle of its diameter, and weighted to half the specific gravity of water. Messrs. Crossly and Goldsmith have also invented a compensating-meter, in which the level is maintained by means of water elevating apparatus or scoop, which supplies water to the meter from a separate reservoir, the overplus returning over the level pipes. This meter was stated to be unnecessarily complicated in several parts, but the relative advantages of buyer and seller very equitable.

Simplicity, after a correct measurement, was stated to be the most important point in a meter. As the apparatus is enclosed in a gas-tight casing which conceals the whole of the working parts, no knowledge can be obtained of the condition of the interior without taking it to pieces.

The compensating-meter, invented by the late Mr. Scholefield, of Paris, was next examined, and some preference shown to it in regard to its simplicity and the arrangement of the supply reservoir, the level of which is below the bent arm of the syphon-pipe or spout.

Also the water-elevating apparatus, which is actuated by means of a crank working in a slot cut in a bell-crank lever, The chief defect in compensating-meters in general was stated to be that the water-elevating apparatus tended to keep the water-line either too high or too low, the extent varying according to the friction of the wheel.

The author remarked that he did not perceive the great novelty in the measuring-drum or wheel recently patented by Mr. Clegg, the design being very similar to, and strictly speaking, an improvement upon, Mr. Malams; the form of the partitions being made in a better shape to pass through the water without offering much obstruction. The novelty being, he considered, the placing of a float within the wheel, which, by supporting it, took the weight off the bearings, and consequently diminished the friction; whether this was advisable or not, experience had not yet proved. In concluding the remarks upon wet gas-meters, it was stated that most manufacturers now cut down the syphon-pipe to the true water-line, and that it was not always necessary in the kind called compensating gas-meters, as the same result was obtained in another manner. There is no doubt of the great service rendered to consumers by Mr. Clegg, the original inventor, as it was chiefly through his invention of the gas-meter that illumination by coal-gas was rapidly increased, and an equitable sale of gas by measurement effected.

The author then described some gas-dial pressure-guages, one invented by Mr. Scholefield of Paris, and another by Mr. Hulett of London; after some preliminary remarks upon the inefficiency of the ordinary tube, gauges, the difficulty of reading off the pressure through the tubes, and the capillary attractions of the same giving a false level to the water, it was stated that the dial-guages were much superior to the ordinary ones, as the slightest variation of pressure was indicated on the dial, and could be read with great facility by workmen, whereas with the tube-guages it was necessary to add the depression of the water in one tube to the elevation in the other. Mr. King's guage was also men tioned, but was thought neither so neat nor practical an instrument as those described.

DISCUSSION.

Mr. Crosley reviewed generally the merits of the various meters brought before the meeting by the author of the paper, and in con-

sidering the question of the water-line, stated that the gas companies complained that it was difficult to keep the true water-line for any length of time, which led him thoroughly to investigate this subject; the result he arrived at was, that he found the water-line, in a majority of the meters he examined, too high, but who it was that thus overfilled the meters he could not say; he thought the consumers, in some cases, did it through ignorance, they thinking that by adding water they improved the illuminating power of the gas.

He then stated that, when in Manchester, he had examined thirty-six meters, taken indiscriminately in the district, twenty-four of which he found registered at various rates of error, from 1 to 35 per cent., and in some as high as 50 or 60 per cent.; and in another town some registered 63 per cent. in error. He mentioned that, in this town, he obtained from some of the consumers their gas bills, and, upon comparing the corresponding quarters' consumption, he was astonished to find so great a difference. He found in one quarter there had been an increase of 100 per cent., the next 130 per cent., and the next 150 per cent.; and he acknowledged, as a practical man, such facts shook his confidence in wet-meters, though he was a meter-maker.

He did not approve of the jumping index, as the spring was very liable to get out of order, and raise the wrong figure, thus registering incorrectly.

He then referred to the number of lights put upon a meter, stating that it was necessary that a meter should not be overworked by having a larger number of lights placed upon it than it was made for, as the vibration increased as the number of lights increased, thus lowering the water-line.

He alluded to the Act of Parliament recently passed, limiting the water-line, so that it could not register more than 2 per cent. against the consumer.

He explained the details of his compensating meter, and thought that the small extra cost of it should not preclude it from taking its position in the market, as he considered that it was not at all complicated, and answered the purpose of keeping the water-line at its proper level, and if the meters were properly filled and attended to, he thought there was no chance of any gas passing unregistered.

June 14th.

ADJOURNED DISCUSSION.

R. M. CHRISTIE IN THE CHAIR.

Mr. Sugg considered the author of the paper had not gone sufficiently into the subject, as there were a large number of modifications and improvements now in use of which no notice had been taken. With regard to compensating-meters, he thought that any meter, having to raise the water to the reservoir by a spoon or any other contrivance, at every revolution of the drum, would cause a great amount of friction which would be detrimental to the accurate working of the meter. He then referred to the plan adopted by the late Mr. A. Wright, who used a sucker, which was raised once to every forty revolutions of the drum. He then explained the working of a meter, and the shape of the measuring-drum from a model.

Mr. Bartholomew considered it was essential both for the gas companies, as well as the consumers, to have a meter that would register correctly, and one that could not be tampered with. He then described his meter, which was a floating-meter, enclosed in an iron case, thus, as he stated, preventing the alteration of the water-line, and also securing it against being tampered with.

Mr. Parkinson stated that the reason why the water-spout was cut down to the water-line was to prevent the meter being overcharged with water. In describing his meter he particularly alluded to the working of the float.

Mr. Mead described his compensating-meter, stating that he used a scoop, connected to a crank on the shaft of the drum, for keeping the water-box or reservoir constantly full; this scoop raised water at every ten revolutions of the drum, from the body of the meter to the small reservoir; this, he considered, answered all the requirements, and kept the water in the reservoir at its proper level, so that the meter would register correctly.

Mr. Willcock, in reply, stated he thought a float was necessary in all meters, and that a great deal of injury had been done by overworking meters, that is, putting more lights to them than they were made for. He stated that he had not yet seen a compensating-meter that he

thought satisfactory, but believed it possible that one could be made to answer every requirement.

The Chairman, in summing up, stated that the great desiderata in a meter were a proper and equitable measuring capacity; and to lessen the vibration as much as possible, so as to keep the water-line at one level, thus ensuring its registering correctly.

September 3rd, 1860.

R. M. ORDISH IN THE CHAIR.

ON THE CHEMICAL EXTRACTION OF GOLD FROM ITS ORES.

BY PERRY F. NURSEY.

The author, in opening his paper, drew a distinction between the chemical, the metallurgical, and the mechanical methods of gold extraction, and pointed out the necessity of a combination of the last with one or other of the first processes. He then proposed to submit the ordinary chemical solvents and tests or reagents of gold, and then the various methods that had been proposed, in which the main feature was the application of chemistry.

The change of colour of gold, under various saturated conditions, and other physical peculiarities of the metal, were adverted to, and its behaviour, when acted on by certain acids and alkalies, noticed in detail. The paper went on to state that a mixture of muriatic and nitric acids (forming aqua regia) most readily dissolved gold which depended on the circumstance that chlorine was evolved by the mutual action of the acids, which element was the proper solvent—other solvents were instanced. The various methods for precipitating the gold from the solution in aqua regia, by means of alkalies, were explained, and a tabular statement of solvents and reagents, with their several results, according to Dr. Lyon Playfair, was submitted.

Some organic compounds, as oxalic acid, or even a seidlitz-powder, precipitated gold readily; in using them it was important that no free nitro-hydrochloric acid was present.

Yellow mica, iron and copper pyrites, were noticed as resembling gold in appearance, and simple methods for distinguishing them by chemical tests were given; or their character might be determined by

the point of a knife, which their hardness resisted, whereas gold was soft and penetrable.

The process of testing quartz containing gold, platinum, and other metals, was explained; and it was stated that the various methods of treatment by the "wet process" were not so generally used as mechanical means, combined with mercurial amalgamation, and dry testing, which latter were in most respects the best adapted for practical purposes.

The earliest practical application of the wet process appeared to be that of Frederick Moult, who, in 1716, proposed it in the reduction of tin ores.

Electricity had been employed for obtaining gold from its matrix in 1844 by J. Napier, and in 1847 Robertson used it in combination with heat for the same purpose. The author witnessed some results in 1853, from the use of the same agents, but considered the conditions imposed by their use incompatible with practice, although he showed its utility conversely in the successful application of electro-metallurgy to the arts.

To remove the zinc that was sometimes present in gold ores, and obstructed reduction, Rowlandson, in 1849, proposed to roast the ore at a low red heat, and then remove the sulphate thus formed by washing in water and the oxide by acid.

William Longmaid, in 1852, fused the ore and precipitated the gold, either by its density or by its affinity for iron, pieces of which were introduced into the melted ore, and afterwards immersed in molten lead, and the gold cupelled from the lead. The author gave the results of a trial of gold ore by this process, the accuracy of which had been confirmed by independent assays.

A flux composed of either soda or potash with lime was used by Pidding when treating the ore in the furnace, and the various mixtures of acids used by him in the wet way were given.

Bursell's system of crushing and mercurial amalgamation was further chemically improved by him, by grinding the ore in a solution of mercury, or of some of its soluble salts. The atoms of gold wetted by the solution on their contact with the iron stirrers caused the latter to become coated with running mercury precipitated from the solution

by galvanic agency; the gold afterwards readily amalgamating with metallic mercury.

The principles of Wagstaffe and Perkins' process were founded on the action of mineral acids upon metallic ores by the collateral aid of voltaic electricity. The ores were roasted, thrown while hot into certain acids, and the metals precipitated by soda or potash from the solution as carbonates, which were ultimately deposited in a metallic state, either by ordinary purification, or by electro metallurgy. The acid solutions were afterwards neutralised by fixed alkalies, which gave neutral salts of the alkalies in a commercial state.

Conceiving gold might be lost in driving off sulphur by roasting the ores, Peter Godefroy proposed to grind and wash the ore and mix it with hydrate of lime, when it was consigned to a digester and kept for five or six hours under a steam pressure of 80 lb. or 100 lb. per inch. The sulphur being thus extracted, the mixture was washed, and the precious metal finally extracted by ordinary treatment.

The author declined offering an opinion on the various chemical methods of gold extraction advanced in the paper without having had practical experience of the several processes. He thought, however, that the agents in each case did not greatly vary. In no instance was it attempted to demonstrate that chemistry alone could prepare and furnish to the world that paramount necessity of her nations, under existing institutions— gold.

DISCUSSION.

Mr. Riley thought that a practical man and not a chemist would find much difficulty in detecting gold by the wet way, when it was present in only small quantity, and might be led into serious error.

Although the tests described by Mr. Nursey answer well in solutions containing only gold, difficulties will be found when it is associated with other metals, and it would require special analytical knowledge to obviate them. The author seemed to think that gold could only be obtained from solution as a black or brown powder; there was, however, no difficulty in obtaining gold from solutions free from nitric acid, in an exceeding brilliant condition, by the use of oxalate or tartrate of soda; the gold is obtained as a brilliant sponge, which is readily welded by pressure, and Mr. Riley proposed this some years since for stopping

teeth, and it has been used very successfully. With regard to the many patents Mr. Nursey had alluded to, he thought they were too complicated, and much questioned their practical utility.

Mr. Smith had been at the gold mines of Australia, where gold was found of different qualities, and was sometimes mixed with a black sand from which it was difficult to extract it. He referred to a paper read by Mr. Warrington at the Chemical Society in January last.

Mr. Riley said he was present when that paper was read, the purport of which was, that Australian gold frequently contained antimony and tin, which made it so brittle that it was not adapted for coinage; and much Australian bar gold had been returned from the mint to the bank on this account. The black sand alluded to by Mr. Smith was most probably stream tin, or sitaniferous iron sand; sometimes sulphide of antimony was also found with the gold, but its presence is most probably due to sulphide of antimony, which is used for refining gold and raising its standard by separating iron, zinc, tin, &c., as sulphides which float on the surface, the antimony thus alloying with the gold ought to be separated by another operation. Mr. Warrington found that by employing oxide of copper, the antimony and tin were completely displaced, the copper alloying with the gold, a certain amount of that metal being required to make standard gold, its presence was rather beneficial than otherwise.

Mr. Louch made some remarks on the extraction of gold by crushing and amalgamation.

Mr. Nursey, in reply to observations made during the discussion, said he feared he had not been understood; what he meant to say was that gold could not be extracted directly from the solution in a commercial point of view.

Mr. Riley made a verbal communication to the Society on the Bessemer process, and also on the manufacture of aluminium and aluminium bronze, promising, at some future day, to bring these subjects before the Society more in detail in a paper.

October, 1860.

R. M. ORDISH IN THE CHAIR.

ON THE CHALK FORMATION.

By JOHN GLYNN, Jun.

The author commenced by explaining how necessary the study of geology is to all engineers, whether for railways, waterworks, or mining purposes, as estimates are often exceeded from a want of careful consideration of the strata passed through in the construction of these works.

The formations above the cretaceous system having been briefly described, the author subdivided the cretaceous system into two formations, the chalk and the greensand. Chalk, the predominant and most interesting feature of the group, was then again subdivided into three divisions, the upper chalk, lower chalk, and chalk marl.

Each of these was considered as of an almost distinct character. The upper chalk, from its porous nature, one-third of which being made up of pores, and also containing layers of flints at distances varying from 4 ft. to 6 ft. apart, and from 4 in. to 18 in. in thickness, As a proof of the regular and steady deposition of the upper chalk, he mentioned one bed or layer of flints, extending between two and three miles, at the cliffs east of Dover. Further evidence of stratification was shown to exist, and to be easily traceable where the chalk is exposed on its escarpment side, in which numerous quarries usually exist.

Besides the nearly horizontal lines of stratification the vertical joints found in the upper chalk were explained.

Tubular cavities or sand-pipes, usually of the form of inverted cones, were mentioned as singular phenomena, which he considered were produced at some time by the water issuing from the chalk being strongly impregnated with carbonic acid, and so carrying the chalk away with it, thus leaving the holes excavated out, the flints where the hole is small having been left *in situ*, while the holes themselves have been gradually filled by the rain washing in the strata overlaying the chalk.

Some noted examples were mentioned at Higham, near Norwich, at Helsenden, and at Thorpe.

The lower chalk was then described as of a much harder and closer

grain than the upper, flints being rarely met with in it, and when so met, only in its upper part, and then not in layers, but interspersed, or what is known by well-sinkers as pudding chalk ; in Yorkshire, however, the flints are there found in layers, in the same way as in the upper chalk of the South of England.

A table was exhibited showing how much more dense the chalk becomes as we descend.

The author considered that the lines of stratification were marked in the lower chalk by hard veins of rock chalk met with in it, of variable depth and thickness.

The chalk marl was then shown to have quite a different description to its predecessor, being of a clayey substance, impervious to water.

Then followed the greensand formation, comprising the upper greensand, the gault, and lower greensand.

Having arrived at the base of the cretaceous system, he then described the principal lines of disturbance, faults, &c., that had taken place in the chalk, and the effect that they have had upon the strata above the chalk formation.

To prove the marine character of this group some of the various fossils found in it were mentioned.

The geographical extent of the chalk was shown to be very great extending to nearly a fourth of the whole area of England.

Its physical aspect he described as unlike any of the older formations, it having such smooth and flowing lines, generally bare of trees, but covered with a short herbage, singularly dry, even in its numerous complicated valleys.

Thus, having given the general features of the formation and extent, the rainfall over it was considered, as the amount falling in a given time was important. He quoted some returns of the rainfall given by the Meteorological Society's tables, which showed as much as ½ in. fell in 5 minutes, and on another occasion 1 in. in 15 minutes. Now, if this quantity fell on an impervious strata, a large portion runs off to feed the streams and rivers, but on the chalk it was immediately absorbed.

The total mean annual rainfall on the chalk formation was taken at 26 in. To account for what became of this water, experiments were

shown to have been tried by various gentlemen to ascertain how much infiltrates into and below the soil, none of which could be entirely relied on, in consequence of the smallness of the areas experimented upon; but the author considered it would be better to take the nearest agreeing with his own experience, although protesting that the only real means of arriving at a just conclusion was by a careful study of the country, its number and volume of streams or rivers, whether fed by drainage or springs.

On the chalk formation scarcely any streams or rivers are found, and those that do pass over it usually rise in other formation. As a practical example a table was exhibited of some cases selected by Mr. Homersham. showing a comparison of nine pairs of bridges with the area of drainage attached to each, one of each pair being on an impervious soil, the other on the chalk formation, in which the comparative drainage areas are as nearly matched as possible. The result arrived at was that the areas of the bridges on the chalk were only from one-fifth to one-tenth the size of those on the impervious stratum, and those in the latter were frequently flooded, while those on the former never varied, and rarely ran more than from one-half two-thirds full.

So absorbing was the chalk found to be that large tracts of clay are now drained into the chalk by means of dumb wells.

The question of infiltration was taken at 42·4 per cent. of the mean annual rainfall, which equal a supply of water to be obtained from the chalk of nearly half a million gallons per day per square mile, for any towns or villages on or near the chalk formation.

The line of saturation or permanent water level was stated to depend on a number of conditions, and was so frequently changed by altered circumstances that the author could not give any direct method of ascertaining it, except by a careful examination of the general character of the strata, the dip, its amount of porosity, height of hills, and the general surface of the country with reference to valleys, &c.

He, however, quoted experiments that have been tried on the north side of the Bexley hills, in Kent, showing the rate of inclination or friction line to be from 45 ft. to 47 ft. per mile; and from another course of experiments from Dunstable to Watford the rate of inclination was

only 13 ft. per mile; and in Hampshire the same rate of inclination, namely, 13 ft. per mile; these can be relied on in the particular line of section taken, but only so; for in one portion of the first-mentioned experiments the author found in two instances the rate of inclination was from 93 ft. to 150 ft. in less than a mile, proving that local circumstances had increased the fall so rapidly.

But even these rates of inclination vary according to the time of year at which the experimental inquiry takes place, as when the springs are at their lowest, which is usually in the month of December, the higher portion becomes depressed or lowered the nearer we approach the outcrop, to as great a degree as from 50 ft. to 60 ft., and lower in valleys on the same line not more than from 6 ft. to 20 ft.

The author then stated that although at the escapement the dip is rapid, the strata speedily lose it, and gradually resume a nearly horizontal position, and these range in gentle undulations until by another flexure they disappear beneath the main body of the Tertiaries.

The causes of springs were explained as a guide in the examination of the best position for obtaining a supply of water, whether by them or the usual mode by means of wells.

Some of the most noted springs mentioned by him were, in the Greenwich and Plumstead marshes, yielding from 200 to 250 gallons per minute. Another group by Northfleet yielding from 5000 to 6000 gallons per minute.

At Erith, within a length of 250 yards, yielding about 1,500,000 gallons per day.

At Grays, in Essex, where a project is on foot to supply a portion of London, yielding 2,100,000 gallons per day.

At Sittingbourne; at Bourne Mill, near Farnham; at Leatherhead, close to the Guildford road; at Croydon church; at Carshalton; at Orpington; the Holy well at Kempering; on the south side of the North Downs; at Birchington in the Isle of Thanet; Lydden Spout, near Folkstone; the Holy well at the foot of Beachy Head Cliff, and at Bedhampton near Portsmouth; and many of these now running away to waste, which could be well spared for the supply of many places adjacent.

The amount of water, carried off by streams and rivers in the chalk

districts, was then compared with the annual amount of rainfall, and under the most disadvantageous circumstances, less than two-thirds of the amount shown to have infiltrated by the gauges previously mentioned was carried off in this form. He therefore considered there was a large amount of water, available for the purposes of town supplies, to be found by means of sinking either wells or bore holes into the chalk; and the quality of the water being with one exception, its hardness, superior to that obtainable from most other sources. Even this objection, he considered, could be easily remedied by a comparatively inexpensive process known as "Dr. Clark's softening process."

With regard to the cost and mode of sinking wells for the purpose of obtaining water, a large number of examples were given with the cost of sinkings, and the yield of them, many only small bore holes of from 6 in. to 11 in. in diameter, yielding 500,000 gallons per day, and of wells yielding from 1,500,000 gallons to 2,500,000 gallons per day.

The methods of boring were explained from the Chinese system of Torscori to the more elaborate method adopted by Messrs. Mather and Platt of Manchester, in which the steam-engine has been made to aid most materially, so that borings, that would, under the old systems of hand boring, have taken years to complete, are finished now in almost as many weeks.

The lecture was illustrated with a large number of drawings of wells, bore holes, and sections through the chalk districts.

DISCUSSION.

Mr. Parsey stated that the paper was a statement of facts that admitted of no argument; but he mentioned that during the excavation for the tunnel at Hampstead a layer of green sand was found embedded in the clay, containing a variety of fossils of fish, different from those found in the main strata.

Mr. Allan referred to the use of the chalk in Brighton district, for carrying off the sewage matter from the houses, which had been found to answer exceedingly well.

Mr. Nursey stated that in consequence of the scarcity of water under London, Messrs. Read and Co. of Grays Inn Road, and Messrs.

Barclay and Perkins of Southwark, were obliged to brew on alternate days, as the day's supply was not sufficient for both.

Mr. Glynn was sorry that more discussion had not taken place on his paper. He considered the questions of filtration, and the quantity of water contained in the chalk, would have led to a variety of opinions being expressed. In referring to the fissures in the chalk, he stated that a well in Harshwell, in Herefordshire, sank by Sir John Easthope to 212 ft., a stream of water was found to pass right through the chalk at this depth, and the force of the water was so great, that large blocks of chalk were forced up the bore hole, and were brought to the surface.

In reply to Mr. Parsey, he stated that he had never heard of the green sand being found in the clay, nor did he think such was the case.

With reference to the absorption of sewage matter by chalk at Brighton, he said that it only proved his argument that chalk was capable of absorbing a very large amount of matter; but with regard to the wells at Brighton, he heard that they required being cleansed very often—in some cases every three months.

He then stated that he contended that chalk was capable of absorbing as much water as could be taken from it; in proof of which he said that at Plumstead Water Works an absorbing well was sunk, 6 ft. 3 in diameter, to 60 ft.; it was then bricked down on to the sand, which was 70 ft. deep. The well was then filled with rubble, so as to leave a space always open; water from the reservoir was then allowed to flow into the well as quickly as possible; and the whole of the water escaped.

The Chairman, in summing up, stated that the information gained from the paper was very valuable, and from the able manner in which the paper was completed, it left very little room for discussion, and had clearly proved that chalk would not only render water in abundance, but would also absorb it.

November 5th, 1860.

R. M. ORDISH IN THE CHAIR.

ON THE PIPE SEWERS OF CROYDON AND THE CAUSES OF THEIR FAILURE.

BY J. T. KERSHAW.

The lecturer commenced with a brief review of the arguments adduced in favour and against using the sewerage of towns for agricultural purposes.

He then gave a description of the situation and peculiar geological position of the town of Croydon, situate as it is at the outcrop of the chalk, noticing the phenomenon of the bourne, and explained the reason of this extraordinary flow of water. He then described the state of Croydon previous to the adoption of the Public Health Act, together with the scheme proposed (and after some modification accepted) for draining the town by means of earthenware pipes; the mode by which the town was supplied by water by means of a well sunk in the chalk, and the question of law to which it gave rise, viz., with regard to the right one has to intercept water in its underground flow, and so by preventing it ultimately rising to the surface, lessen, the volume of a stream of water turning a mill whereby the mill owner is injured.

He then proceeded to notice the causes which produced the fever in Croydon, and explained that, in consequence of the drain pipes sinking, owing to faulty execution, they, by retaining water, dammed back a quantity of air, which became putrid, and which air, by pouring more water into the drain, was forced back into the houses, and thus produced sickness.

The lecturer then gave an account of the successive obstacles and difficulties which were thrown in the way of the local authorities in consequence of the failure of their plan of filtration and deodorisation, whereby the water of the Wandle became fouled, causing the mill owners to complain and to take proceedings to prevent the flow of sewage water into the Wandle.

He then reviewed the errors in principle, which had been committed both in the original design of the system and in the construction of the new filter house, and showed that it was not possible to filter sewage

water by forcing it at high velocity through a small vertical filtering medium, but that the proper way, if it must be filtered at all, is to let it ooze through a considerable horizontal surface.

He then stated that the authorities had ultimately adopted the plan of turning the sewage over a small farm which they rented.

The lecturer then concluded by describing a system of sewage combining the cesspool with the pipe drain, which system he submitted would enable the sewage to be *profitably* used as manure.

DISCUSSION.

Mr. Fenton stated that, although Mr. Kershaw had considerable knowledge of the system of sewers at Croydon, he did not appear to be aware of what had been recently effected; being the engineer to the board, he could point out some of the errors of the paper.

The pipe service has *not* been abandoned, but is still used to a considerable extent more especially for the branch sewers.

Nor is the water in the river mixed with or polluted by the sewage, as that is now avoided in almost every case.

The purification of the sewage water was a very difficult process, as, although the water might be made as pure as crystal by either perchloride of iron or by lime, it soon became quite cloudy and unfit to be sent into a pure river. Irrigation fields afford undoubtedly the best means of disposing of the town sewage.

The system adopted at Croydon is to subject the sewage to rough filtration, and to allow it to flow over a portion of the land for about a week, then to divert it to another portion.

The crops produced by this system are magnificent, and the cattle feed on them with avidity, and in preference on that herbage over which the greatest quantity of sewage has passed.

Since the completion of the sewers in Croydon the health of the town has so far improved, that the annual rate of mortality is now only 15 in 1000, the average for all England being 22 per 1000. Mr. Kershaw's plan of street cesspools would, in his opinion, be worse than the disease.

Mr. Drummond submitted an explanation of the cause of the flow of the bourne different to that usually accepted, viz., that it arose from

the recesses in the hills becoming surcharged, as it had been observed that, when the rain-fall did not exceed thirty inches, there was no flow whatever, but it invariably flowed in seasons when the rain-fall exceeded thirty inches.

The deodorisation of sewage could not be effected by lime, inasmuch as it was adding that which entirely destroyed its value as a manure.

The Croydon sewage is distributed over a hundred acres of land, about fifteen acres at a time over which it is allowed to pass for about a week, and is then directed over a similar quantity. It is perfectly harmless and in no case offensive, and the water which drains off the fields is perfectly pure; the vegetation having deprived it of all chemical and impure matter, and the soil of everything mechanically suspended in it, the process was so satisfactory to all interested that he had never heard a single complaint. As regards the material for sewers he, from experience, would recommend pipes for branch sewers up to ten inches in diameter; but for main sewers and branch sewers above that diameter, brick sewers were no doubt to be preferred.

Mr. H. P. Stephenson fully concurred with Mr. Drummond in his last statement, but reminded him that the Croydon Board had originally intended to construct their sewers entirely of pipes, which system they would probably not now advocate. Mr. Kershaw's plan appeared to possess no advantage over the old system of cesspools, except perhaps that of affording more convenience for emptying, while the separation and loss of all the liquid and valuable part of the manure would render the residue of no value as a manure. The plan adopted at Croydon had also been tried at Watford and Rugby, but in the latter case with no advantageous result, the fields being in some cases very offensive, and the effect on the crops not what was expected. The Leicester sewage has been deodorized with lime, but the product cannot be sold so as to realize a commercial profit.

Mr. Riley said there could be no greater mistake than to suppose that the solid part of the sewage was of any value; it is merely the soluble part that gave it value. The chief difficulty to be contended with was the amount of water mixed with a comparatively small portion of soluble matter. Soil is the natural as well as the best purifier of decomposed matter, which it deodorises and prepares to be

taken up by the roots of plants. Animal and peat charcoal are the only actual deodorisers we know of, but their application on a large scale would be difficult and expensive. The separation of the solid from the liquid matter is quite useless, as it would be much better to pump it at once on to the land, taking care to proportion the quantity to the surface operated on.

Mr. Morris described a plan somewhat similar to the cesspool plan of Mr. Kershaw, but more perfect, viz., that advocated by Mr. Kirby. The sewage is removed from the cesspools by back drainage, thus dispensing with the use of carts, and is then mixed with sulphuric acid.

Mr. Ormiston was of opinion that pipes were quite inadmissable as main sewers, except in cases where great falls could be obtained. He alluded to a town containing 400,000 inhabitants, where deoderisation had been tried unsuccessfully with both lime and charcoal. The common-sense plan was no doubt to spread the sewage over the meadows; there was, however, great difficulty in procuring sufficient area of land near large towns.

Mr. Siebe described the cesspool system adopted in Paris as being very offensive and unwholesome. The cesspools there are emptied by means of carts constructed like boilers, and in which a vacuum has been previously formed.

Messrs. Willcock and Young confirmed the opinion of the last speaker as to the offensive nature of the cesspool system of Paris, and did not consider that Mr. Kershaw's plan would be any improvement on it.

Mr. Fenton, in reply to questions from Mr. Gray, stated that fourteen acres of land would take all the sewage of Croydon for a week, the substratum being gravel; in fact, he had good rye grass growing on the bare gravel, nourished by the sewage alone. During the first twenty-four hours none of the sewage passed over the land, but by the end of the week as much passed over as through.

The Chairman considered the result of the discussion appeared to be that the use of pipes in town drainage was only advisable to a certain extent. Irrigation appears to be the only way of disposing of town sewage, but the main difficulty seems to be to obtain a sufficient acreage to absorb it. Lime as a deodoriser has in every instance failed, and its use is almost universally discontinued. He considered the

subject one of great importance, and from the paper and the discussion much valuable and practicable information had been elicited.

December 3rd, 1860.

H. P. STEPHENSON IN THE CHAIR.

ON STREET RAILWAYS.

BY CHAS. L. LIGHT.

The author, after adverting at considerable length on the origin and progress of tramways, in which he proved that, for a period of 200 years, they had formed an important feature in the mineral working of this country, and in later years had, in various parts of the kingdom, been used under various modifications, for the transport of passengers and merchandise.

During his residence in Paris, in 1853–4, he had the opportunity of witnessing the construction and working of, he believed, the first horse railway in France, viz., from the Place de la Concorde to Passy; and although the system as there applied contained many good features, still for street traffic or crowded public thoroughfares there were many points highly objectionable. Since that period an extension of the system has been made with various modifications.

In New York street railways have been in use for some eight or ten years, having been introduced by a Frenchman (Loubat) whose name is well known in connection with the system. In the extension of the system in New York by other companies various modifications have been made, none of which, however, answer the purpose satisfactorily, at least so far as their effect upon the ordinary street traffic is concerned.

The badly-built track, dangerous rail, and miserably constructed cars of the New York street railways, tended greatly to throw discredit on the system generally, and for some years prevented their adoption in other cities, and although in Boston (which was the second city in America to adopt them) various companies had held Acts of the Legislature for the construction of street railways, for a period of two or three years they could not obtain a location for a single line in any portion of the ci'y or its suburbs. To the New York (and the then only known) principle, great opposition was brought to bear, by influential bodies, and owners of real estate, on the various proposed lines of route.

After considerable agitation and the expenditure of considerable sums of money in opposing the scheme, the author was consulted by various parties holding these charters as to the best means of getting over the difficulty.

The subject, and the many difficulties he had to contend with (and there were many, some of them live ones, and there are a great many such on the other side of the Atlantic), cost him much and anxious consideration. At length, however, he overcame them, as may be seen from the section shown in Fig. 2.

Having accomplished this result, he submitted his models to several influential gentlemen, who highly approved of his plan. He laid them before the municipal authorities in council, who were so satisfied as to its superiority that he immediately received permission to lay down a section of the Metropolitan line between the cities of Boston and Roxbury, consisting of a double line 1⅛ mile long.

One month only was given him for its accomplishment, and he had the satisfaction of completing it in twenty-one working days, and with this gratifying issue, that he not only received a very handsome bonus, but had immediate orders to proceed in the construction of this and other lines. The hitherto principal opponents to the scheme being so satisfied with his improvements that no further opposition was offered in any quarter, and the system was carried out in the city of Boston and its suburbs to the extent of nearly fifty miles.

At the time of commencing the construction of street railways in Boston he had not visited New York, and was consequently unacquainted with the exact principle of construction and condition of their roads.

In the month of February, 1857, however, while travelling through the States, he had ample opportunity of examining the New York street railways, and he was not at all surprised at the amount of opposition brought to bear against the introduction of the system into other cities of the Union.

The rail Fig. 7 was of the worst form for ordinary street traffic, and from the method of fixing it to the longitudinal sleepers was so soon thrown out of order, that in a short time it became a perfect nuisance, and exceedingly dangerous for the wheels of other vehicles to come in contact with.

Owing to the stringers or longitudinal timbers being chamfered to permit of the saddling of the rail, there was very little actual bearing for the rail left, and the result was (particularly at the intersections of streets), that

from the constant transverse traffic of heavy teams, the rails were in a very short time worn loose upon their bearings, and in some instances he had witnessed the rails when the car has passed on to one end of its lengths, rise up on the other end, and, falling, send the mud flying in all directions.

The only reason he could assign for this state of things being permitted was the fact, that the groove in the rail was so dangerous to the light wheeled vehicles of New York, that the drivers shunned the track altogether and left them, without complaint, an uninterrupted right of way, at least so far as the tracks were concerned.

The bad condition of the rails necessarily rendered the pavement bad also, and the ruts and pools were such as would not have been countenanced in any city or town in England for a single day.

It will be at once apparent to any practical mind that a perfect system of paving in connection with street railroads is of the first importance, and for this reason, because ordinary vehicles of this or indeed any and every other country, are not gauged to one track, but range from a gauge of 4 ft. to 7 ft., and as in practice it is proved that drivers will on a good line of street railway, invariably drive with one wheel on the track, it results in the tendency to wear a rut on the outside of the opposite rail, much to the detriment of the track and roadway.

This fact determined the author to pave on the outside of the rails with block paving in courses, header and stretcher as in Fig. 1, of granite, to obviate what appeared to him (and which in practice proved to be the fact) this difficulty, which would prove so detrimental to the cause and action of tramways.

Several companies objected to this system of block paving on the score of expense, and, in some cases, his arguments in favour of its adoption were unavailing, until after the lines were worked for some time and the treasurer was called upon repeatedly for sums of money for the repairs of paving when it was decided to adopt his plan.

The item of paving in the proper construction of a street railway, either for city or suburban routes, is one of the most imposing, but, notwithstanding this fact, it is of the utmost importance to have it done thoroughly well at the outset, and he thought that, with a concrete bottom and grouted in as in London city paving, it would prove the cheapest in the end.

During the past ten years there have been many attempts made to intro-

duce street railways in London, and many different plans have been devised by as many different persons, but, up to a very recent period, without success.

Three years ago, on the author's return from America, about the time that the "London Omnibus Tramway Company" were applying for powers, he waited upon the secretary of that company, and, at his suggestion, he saw Mr. Samuel, their engineer, who was then engaged upon a plan which he felt sure would meet the fate which it did, and which it deserved.

He was invited to send in his plans, but time did not allow of his doing so before the bill was rejected by Sir Benjamin Hall, and so the affair (for the time being) fell to the ground.

Since then he had taken every opportunity of advocating the introduction of street railways for passenger traffic, and laid his plans before Sir John Ratcliffe, when Mayor of Birmingham, Alderman Kinahan, of Dublin, and other influential men, but without any practical result. The attempt to introduce the system into England is no novelty, but has been advocated over and over again by different parties (Mr. William Bridges Adams among the number), long before its introduction into New York, but has as often failed, owing, no doubt, to the want of sufficient supporters, coupled with the almost insurmountable difficulties always thrown in the way of every new project, however good it may be.

Thus its introduction, in a practical character, in this country is made by an American (Mr. George F. Train), who has unquestionably exercised a vast amount of talent and energy, coupled with a fair proportion of tall argument in support of the scheme, not forgetting the interests of sundry speculative Americans.

To Mr. Train there is, without doubt, a vast amount of credit due for the unflinching way in which he fights the up-hill battle he is engaged in; and although he acted most judiciously in practically developing the system as at Birkenhead, the author considered he had made a fatal mistake in laying down so imperfect a rail—imperfect, because it is a nuisance to the ordinary traffic, and one of the worst sections that could be devised.

This is a serious matter, for, as bad news always travels faster than good, so is the fact of this rail being a nuisance within the knowledge of every one at all interested in the matter throughout the whole country.

To construct a tramway or street railway sufficient for the purpose of a

tramway proper, is one of the most simple things imaginable; but to construct a street railway to meet all the contingencies of a tramway, to obviate difficulties with the ordinary street traffic, and to leave the public thoroughfares in a condition above all fear of dissatisfaction, is a very different matter, and oné that challenges (if the scheme is to be brought to a successful issue) the most serious consideration of all parties concerned; and, as Mr. Train has borrowed his designs and *patented improvements* in track and cars from one source or the other, the wonder was that he had not borrowed a better style of rail.

Usurpers invariably "put their foot in it" somewhere, and this is Mr. Train's quagmire. The line, as laid at Birkenhead, as a pattern-card of the system which he advocates, the author feels satisfied will meet with disfavour, and even supposing it is allowed to pass muster at Birkenhead, he is certain it can never be laid with success in the thoroughfares of the metropolis.

The reader's objections to Mr. Train's rail (Fig. 6) are these:—First, it offers a great impediment to the public traffic, and is consequently a nuisance, and would be complained of as such. Again, the rail as laid (and also, according to the specification of patent recently obtained by Mr Train), is not level with the street; neither has it a groove, but a raised surface or tread, ¾ in. to 1 in. above the plate or base of the rail (we will assume this raised surface or tread to be level with the ordinary surfacc of the street), and, consequently, the base plate of the rail (to allow of the free action of the flange of the wheel) and also the pavement between rails, must, of necessity, be from ¾ in. to 1 in. below the street-level. Thus it is obvious that the breaking up of the surface of the street is both dangerous and difficult to the traffic of ordinary vehicles. But this is not all: supposing that one wheel of an ordinary street vehicle is running upon one rail of the track, and has occasion to turn out on the side on which the wheel is binding or shouldering on to the tread of the train rail, he contended it would be impossible to do so at a less angle than 45 degs., which would invariably be unattainable in the crowded streets of London, or, in fact, in any important city whatsoever.

Thus the result would be either a wrenched wheel, or what is quite as probable a serious accident.

The author was sure, it would be at once obvious to every gentleman

present that, in the generally greasy condition of our streets, it would be impossible for a wheel to mount the raised ledge of this rail at an obtuse angle.

The author finds, also, in Mr. Train's specification, that he claims the use of the two inner rails of a double track (or, at least, the base plates of those two rails) as a tramway for ordinary wheeled vehicles. This, in practice, would certainly prove a fallacy, for the variety of guage of our ordinary vehicles would render it not only useless but dangerous; and we should find some few vehicles that would gauge sufficiently nice to become locked in the embrace of the raised portion of the rail.

The reader advanced these objections simply as matter worthy to be discussed, and with a desire for the development of the system of street railways in this country in its most perfect form, and, therefore, in that form which shall tend to its certain success.

He was inclined to think that Mr. Train has doubted the success of this rail for London, or why not have long since given a practical test of the system in some of the suburban thoroughfares which have been "located" to him? and thus in solving the problem, closed the mouths of the opponents to the scheme, who are daily becoming more powerful.

Mr. Train is unquestionably a most able and energetic advocate, and has worked well for those speculative Americans by whom he is accredited to carry out their scheme. You may rest assured of the fact that there are some very large *plums* in the *tramway pie* to induce American capitalists to invest their money in the scheme in this country; to agitate the question among the whole community; to publish addresses and pamphlets; to get up flaming lithographs of borrowed designs, &c., to say nothing of the expense of getting up cards of invitation to the crowned heads of Europe—are in themselves facts which leave little doubt as to the result to be obtained from the American introduction of street railways in England.

We have pretty good evidence of what might be the result, from the fact that on the introduction of the system into New York the lines were constructed by a few enterprising individuals at a cheap rate, and afterwards transferred to a company, on consideration of its shareholders subscribing to the tune of 300 per cent. on the original cost of the line.

Among the various systems proposed for the furtherance of the scheme, and for which the sanction of Parliament is sought, is that of Mr. Hugh

Greaves, in which he proposes to construct a street railway combined with a system of double breasted gas or water mains or pneumatic despatch pipes. This sort of thing may be very well in theory, and may look very well on paper, providing it is nicely coloured; but in the author's opinion it is too complicated in its character ever to arrive at any practical issue.

The difficulty of making connections, of harmonising the route of a street railway with a gas, water, or Pneumatic Despatch Company would prove difficulties not easily surmounted; again, to lay pipes sufficiently near the surface to form a compact superstructure, and to admit of perfect paving would, I think, be troublesome matters to contend against; I am inclined also to believe that a superstructure of cast-iron pipes would emit a very disagreeable rumbling metallic sound on the cars travelling over them.

There is, however, in Mr. Greaves' proposed plan much novelty, the advantages of which can only be developed by experiment.

Another plan spoken of, and which there is some talk of bringing to a practical test, is that of Mr. Curtis. His proposition is to construct a carriage (in fact one is already constructed and can be seen on the platform of the Great Northern Railway at King's Cross) like a monster omnibus and a railway car combined, capable of accommodating 50 persons, to run on rails or macadamised roads at pleasure, or *vice versa*, drawn by a couple of ordinary London cab horses.

The carriage to weigh 3 tons and its load 4 tons more: thus we are informed by Mr. Curtis, in his letter to the *Daily Telegraph*, that with this load of seven tons drawn by two ordinary cab horses, he can travel at the rate of eight miles an hour, including stoppages, leaving one track for the other or running off the rail altogether.

He would not dwell on this extraordinary proposition further than to state that he had seen the carriage of Mr. Curtis passing through Westminster drawn, he believed, by four horses, and a pretty hard task at that without any passengers.

Besides it is a proposition from which no good results can be obtained, and is at once a departure from the true theory and action of tramways.

The meaning of a tramway or street railway is a road by which the maximum load can be advantageously worked by the minimum expendi-

ture of power. Now, in Mr. Curtis's plan, this principle is set aside; for a departing with a load of seven tons from the rails is at once departing from the advantage of a street railroad, and bringing it with its load to a dead lock.

In Manchester Messrs. Greenwood, the omnibus proprietors, are experimenting on a somewhat novel adaptation of their omnibuses to the tramway system. If he was rightly informed, they are laying down iron tram plates of the gauge of their omnibuses, and level with the surface of the road, and in the centre between the tracks, a grooved rail; under the centre of the carriage is rigged a guide wheel which can be raised or depressed at the pleasure of the driver, into or out of the centre of the grooved rail, and thus form another application of the tramway system to existing omnibus stock. It is certainly a novelty and worthy of the experiment Messrs Greenwood's are making, but he feared would not be found of much advantage over the old stone tramway in practice.

The plan the author most strongly advocated for street railways, and to which he drew especial attention, is shown in Figs 1 and 2, and as a natural consequence it was his own; his reasons for arriving at this most favourable conclusion is not based altogether on the theory "that every father thinks his own child the fairest," but on the fact that, in practice, it has proved the most simple in its construction, the most efficient in its working, the least objectionable to the ordinary street travel, and the cheapest in its cost and maintenance. These assertions he was in a position to prove by the testimony of very high authority, among whom he mentioned Mr. Enoch Train, the eminent American shipowner, and relative of our enterprising cousin, George Francis Train.

On referring to the drawing it will be seen that the superstructure is of timber, and constructed somewhat in the usual manner, with one or two improvements to which he invited especial attention.

The timber used is spruce fir, cross-ties 6 in. × 6 in. and 7 ft. long, the longitudinal 8 in. × 5 in., in lengths of from 15 ft. to 18 ft.; in notching out the cross-ties (which are placed 3 ft. apart) he preferred to undercut it to better hold the longitudinal, which is cut tapering in its section, and, by means of the hard wood dove-tailed key, is the more firmly secured in its position; the whole of the timber should be Burnettised to prevent its decay and, when properly straightened up to its defined line, and well packed with

gravel, at once renders it a most permanent and elastic superstructure; the section of rail shown has the advantage of having a bearing its whole width, and, when spiked down with ½ in. spikes, 6 in. long, is immovable. The advantage of this section of rail over all others is simply because it offers no impediment to the ordinary traffic, and is perfectly level with the surface of the paving; the groove, if it can be termed such, is only sufficient to allow of the free rotation of the flange, which, in its action, frees itself from the obstructions of stones or mud, by forcing it up the inclined plane of the inner section of the rail; the peculiarity of this section obviates any difficulty to the free action of ordinary wheels, inasmuch as we have no tyres in this country sufficiently narrow to be affected by it; and if by any possibility tyres should be found sufficiently narrow to feel in any degree the effect of the groove it is immediately freed by the slightest deviation from the course of the tramway, and then mounts the inclination of the plane.

The rails used by the author in America were of cast iron, in 6 ft. or 8 ft. lengths, the ends were provided with dowells and cores placed diagonally, which entirely prevented working at the joint, and when secured to the longitudinal timber, with four spikes to each length, left it as near a continuous rail as possible. His object in using a cast-tron rail in such short lengths was to obviate a difficulty which is brought about by the action of the frost on the surface of the ground, or rather the breaking up of the frost, for by its expansion from thawing, the surface of the roads are lifted into transverse undulations, and, lifting the track, bend the rail where wrought-iron rails are used, start the spikes by which they are secured, disturb the joints of the rails, and after the roadway assumes its original surface leave the rails "hogged up," and away from their superstructure. The short rails and dowells obviated this difficulty, by acting as jointed vertebræ.

In this country, there being no similar cause, there is no necessity for this provision, and the same section of rail may be used in wrought-iron in long lengths, with a similar provision of dowells for the security of the joints.

Assuming that we have a perfect system of tramway judiciously located, and well constructed, they are unquestionably an immense advantage for city and suburban traffic for all large and populous districts, and admirably adapted to new countries, and more especially to our colonies, where the

present system of expensive communication cannot be maintained without positive loss to the proprietors.

Among the many advantages enumerated in favour of this system in new countries, or where it would be injudicious to resort to the more expensive methods of railway construction, are the following, viz., cheapness, simplicity, and rapidity of construction, economy in working expenses, comparative small cost of maintenance, great advantage as military roads in offering facilities of transport from settlement to settlement, and in the great advantage to agricultural districts in the transport of produce and merchandise.

The system he should propose for new and isolated roads in colonial settlements would consist of an elevated track or embankment, say, 3 ft. high, with dykes on either side, and with a formation level of not less than 9 ft. in width for a single track, such surface to be macadamised level with the rails to form a perfect highway suitable for the passage of troops, &c.

The cost of such a single line of tramway and embankment to cost not exceeding £1,200 per mile, or a double line of rails for up and down traffic, with the surface of roadway 25 ft., £2,400 per mile; such roads could be easily widened out and improved as progress of time might require, with great facility and small cost by means of such tramways.

In London particularly there is much to be considered, and seriously considered too, prior to their introduction into our crowded thoroughfares. Firstly, he considered it would be a most hazardous proceeding to attempt to introduce them into the streets of London (even with the sanction of the vestries), without an Act of Parliament, for it would involve the question of the right of any parish or municipal body to give the monopoly, or exclusive right of way, to any speculative body or public company. An Act of Parliament would not only give power to the projectors, but would give protection to the public, and ensure the adoption of the most perfect system; for he presumed nothing would be adopted until its merits and demerits were fully discussed and approved by the engineers appointed for the purpose by the Board of Trade.

Assuming its adoption in the metropolis, he was convinced no route could be worked successfully without a double track; and to allow of this, no thoroughfare can be traversed, less in width than 35 ft. between the curbs, with safety; for, allowing a gauge of 4 ft. 8½ in., and bars 7 ft. wide over all, with a space of 2 ft. between the bodies of the cars, we shall have only

9½ ft. on each side of the street left for the passage or ordinary vehicles. It is urged that, where the thoroughfares are too narrow to admit of a double line of rails, the difficulty can be overcome by working single up and down lines in parallel streets, as in Philadelphia. He would readily grant that it might be done in a city so beautifully laid out as Philadelphia, with its streets running at right angles to, and parallel with each other in its whole length and breadth; but in London or any other English city, excepting in some few instances, it would be totally impossible to carry out such a proposition to any useful extent; no street, even to admit a single track, could be successfully worked with less than 25 ft. between the curbs, for the reason that, in all cases, the double or single track must be laid in the centre of the street, to admit of teams or vehicles drawing up to their destinations and discharging their loads or occupants, as the case may be.

With these objections and difficulties surmounted, street railways are a great institution, and offer such advantages over the present miserable omnibus system, that, sooner or later, it must (where feasible) be adopted and come into general use.

The advantages of the system are many:—Firstly, in crowded cities, it is a boon, inasmuch as cars occupying less space in width carry double the number of passengers, thus reducing the number of passenger vehicles one-half, and confining those vehicles to one defined line of travel.

Increased comfort to passengers, with greater safety and less noise, a great reduction in the wear and tear of public thoroughfares, and consequently a great saving to the ratepayers.

Greater facilities of ingress and egress to the passengers and steadiness of motion, a greater rate of speed is obtained with a less tax upon horseflesh, a load of sixty passengers being drawn at the rate of eight miles an hour with ease, by a pair of cobs, which last longer and thrive better than under the omnibus system, their greatest task—that of stopping the vehicle on the slippery pavements—being transferred to the brake. These are some of the many advantages of street-railways over the omnibus system for city and suburban traffic. For short branches to steam roads and for local traffic, tramways are admirably adaptod, and, if introduced years ago as branches of our main lines, would have acted as tributaries rather than the drains which our expensive branch lines have proved to be in a financial point of view. As an investment we can have no better proof of the fact than that

Americans are not only willing, but are spending enormous sums of money in endeavouring to obtain the monopoly for their construction in this country.

For statistics of cost, working expenses, and returns of lines in operation in America, he could not do better than refer the meeting to the interesting pamphlets published by Mr. Charles Burn and Mr. Train.

In concluding this paper, he mentioned that his object and endeavours had been to lay before the members his opinion, based on personal experience of the various systems of tramways proposed for adoption in this country, of their merits and demerits, with a view to arrive at the most perfect system rather than that a good thing should be spoiled by a bad adaptation of it. If his humble endeavours had thrown any light upon the subject, or in discussion they should tend to any improvement and further developments of the system, he was gratified and rewarded for his pains.

January 14th, 1861.

J. AMOS IN THE CHAIR.

ON STREET RAILWAYS.

BY C. L. LIGHT.

DISCUSSION.

Mr. Curtis said that he had lived sufficiently long to know that there was nothing more agreeable than to pass compliments upon those with whom they were associated; and therefore it was that he could not help speaking of the valuable informtion which Mr. Light had given them in his paper. With regard to the tramways in France, he might state that in the years 1853 and '54 he had an opportunity of witnessing the construction of the extension of the Passy line to the Place de la Concorde; he had also a personal acquaintance with Mr. Loubât, the inventor of that system, a gentleman of high and scientific attainments. He considered his cars very good, and he had no doubt but tramways were very good things if they could overcome those objections, which would unavoidably attend their introduction into this country, namely, right of way, &c. Mr. Loubât had a double line of tramway for a certain distance, when the line diverged, which got over the difficulty of encountering carriages coming in an opposite direction. It was quite true they could get off the rails easily enough, but it was with

great difficulty the carriages could be got on again. Mr. Loubât had told him that on a paved road the rails were kept very clean, and worked well, but when upon macadamized or gravelled roads, the grooves become filled, which completely paralyzed the whole affair, not excepting the poor horses. The remedy was this: they reduced the flange of the wheel, giving more clearance; which made a most material alteration for the better. Mr. Loubât showed him that the flange was a distinct wheel which obeyed the law of its own motion. The rail required for a public road must be of the narrowest kind possible; and the greatest fault in the section before him (No. 7) was, that if a horse was taken over the line it would invariably dislocate its fetlock; and he did not believe such a rail would be at all adaptable to London.

Mr. Curtis then described his own patent street railway car, to which he used two wheels (instead of one wheel with a flat tyre and flange, as used on railways), the flat tyre to receive the weight was upon one wheel, and the flange for guidance on another. Being placed in juxtaposition, the two revolved about the same axis, and operated as one, serving all the purposes of a flanged wheel. By a system of leverage the flange wheel is lifted off the road, leaving the tyre wheel untouched. The carriage so furnished might be made to traverse a road where there was no tramway, and differing in no respect from the carriages in use on every turnpike road. By putting the lever into action the wheels ceased to be flanged, the car could leave the tramway, traverse the common road in order to pass the car which had possession of the rails, and then, by putting the flange in action, again pursue its journey on the rails as before.

Mr. Waterhurst considered there was nothing particularly new in any of the sections of rail exhibited. He had had considerable experience in railway and tramway matters in connection with the late Mr. Brunel, on the Great Western Railway. With regard to the practicability of laying down tramways he could not for one moment conceive the possibility of laying down a line from Temple Bar to Ludgate Hill either with profit or advantage. There were vested rights to consider; and obstacles would be created by men of influence. He thought tramways might be laid with great advantage on circuitous routes from the west to the south-west, to the city by the Surrey side route, but he

did not think that street railways would ever become general in crowded thoroughfares. In country and suburban districts they would be of great advantage. With regard to Mr. Curtis's carriage he considered it possessed great advantages over any other that he had seen. The simplicity with which it was converted from a railway carriage into a common road carriage he thought admirable. He did not see the slightest difficulty in doing what was proposed, viz., in running on and off the rail at pleasure.

Mr. Glynn had heard that a great objection to Mr. Curtis's car was the difficulty of stopping it,—that his carriage, travelling at the rate of eight miles an hour could not be stopped in a less distance than 250 yards. He had seen one of the London three-horse omnibuses, with a load of forty-two passengers, stopped on a slippery tramway of stone, in a space of fifty yards; and he did not see why a car with a load of fifty passengers could not be stopped in the same distance, if the breaks were properly managed. He considered the objection urged against Mr. Curtis's car would be entirely obviated by a better and more perfect application of break.

Mr. Curtis replied by stating that the breaks used on his car were precisely of the same powerful character as those used upon railways. With regard to the regulation of the flange, it was but the work of a child.

Mr. Meredith thought the construction of street railways with cast iron rails was quite impracticable, as they would constantly be broken by the cross traffic, and likely to give way at the joints, which he considered should be firmly fixed on a hard bearing, and he was of opinion that if street railways were introduced at all in the proposed form, the permanent way would have to be gradually increased, until they were as strong as any of our railways, before all the difficulties would be surmounted.

Mr. Le Feuvre had understood from Mr. Train that the cast iron rails introduced by Mr. Light in America had proved a failure.

Mr. Lockwood considered that an important element in the construction of street railways was to ascertain the cost of the horse power.

Mr. Riley considered the cost of the horse power was one of the first items to be thought of; for so great was this expense found to be in

large iron works in Wales, where the system of horse railways had been in use for a very long period, that locomotives were now in nearly all cases taking the place of the horses.

Mr. Young was of opinion that all systems of street railways should have a fair trial, until one was found to overcome the various objections. He estimated the cost of the horse power at ninepence to a shilling per ton per mile, whereas steam on common roads cost only threepence per ton per mile.

Feb. 4th, 1861.

H. P. STEPHENSON IN THE CHAIR.

(Adjourned Discussion.)

A communication from Mr. Brydges Adams was read by the Hon. Secretary in which he advocated the use of locomotives as preferable to horses for street railways, and thought that such railways would never be sanctioned in the crowded thoroughfares of the metropolis.

Mr. A. Williams considered that any rise of the rail above the roadway would be detrimental to the general traffic, and that if street-railways were adopted it would be necessary to obtain an Act of Parliament, in order to secure the vested rights of the inhabitants, and thought that from the position occupied by such tram-roads, viz., on the surface of the roads, they would be justly liable to a higher rating as compared with gas or water-pipes.

Mr. Smith thought that street railways would prove a good investment—as in New York, Tramway Stock was about the best in the market—and if the New York system laboured under the disadvantages spoken of in the paper, he saw no reason, if these disadvansages were removed by constructing the roads in an efficient manner, why they should not pay much better. He had seen the tramroads in New York in a very bad condition and full of holes, but still, even with very inferior horses, the cars travelled very fast. He advocated the use of large carriages, as much time was saved by the conductor having the facility of being able to pass up and down the centre to collect the fares during its progress.

Mr. Louch advocated the use of small locomotives on tramways in suburban districts in preference to horses.

Mr. Glynn stated that tramroads judiciously laid down would act as feeders to the main lines of railways, and could be made available both for passengers and goods traffic.

Mr. Light, in reply, stated he did not advocate the introduction of tramways into the crowded streets of the city proper—feeling that it is next to an impossibility to do so to any useful extent. He saw no possibility of crossing the city of London with a tramway, except from north to south by way of Farringdon-street and Blackfriars-road; true, it is quite possible to run a line from Bayswater to Farringdon-street by way of Holborn, but no farther eastward. Where, however, any line can be laid perfect and independent in itself the omnibuses of these lines would be taken off and the street railway cars would take their place, offering many and unmistakeable advantages, teamsters would soon be taught to respect the law of tramways—for he assumed that no one would attempt to construct street-railways until their introduction is legalized by an Act of Parliament, for he contended that it would be madness to attempt to do so without one, as it would inevitably lead to a battle of right-of-way. In the United States this question is entirely settled by a clause in the Act of the Legislature of Massachusetts as follows:—" Sect. 4. If any person shall wilfully or maliciously obstruct the said Corporation in the use of said road or tracks, or the passing of the cars or carriages of said Corporation thereon, such persons, and all who shall be aiding and abetting therein, shall be punished by a fine not exceeding five hundred dollars, or may be imprisoned in the common gaol for a period not exceeding three months. If said Corporation, or its agents or servants shall wilfully and maliciously obstruct any highway, or the passing of any carriage over the same, the said Corporation shall be punished by a fine not exceeding five hundred dollars." Thus it will be seen, lawful protection is given to the Tramway Company and to the public. Some gentlemen question the possibility of traversing sharp curves with tramways, he could assure them there was not the slightest difficulty. He had worked curves of 33 feet radius without any trouble.

Cast iron rails laid in combination with a timber superstructure, as shown in Figs. 1 and 2, are equal to any weight that ordinary street loads would ever subject them to: he would have no fear of running a 30 ton locomotive over them at a speed of 20 miles an hour. After his own experience in the use of them in the States where, during a period of two years,

along a dock side road with heavy teams continually traversing, he never knew an instance of a broken rail.

It is stated that they will wear out rapidly, and that in Boston they were found to be a failure, *except on curves.* In reply to which he could assert most positively that it was only at the curves that there was any visible wear and tear after a use of two years, it stands to common sense that at curves of 33 to 40 feet radius, traversed by cars with their wheels keyed fast on to the axles, there must of necessity be a good deal of wear and tear at those points, and which would be considerably reduced as the cars left the curves for the straight line; of one thing, however, he felt satisfied, and that was, that the use of cast iron wheels with chilled tyres tend greatly to wear out cast iron rails, and he should always advocate the use of a wooden centered wheel with a wrought iron tyre for the purpose of a street railway.

To use cast iron rails without the interposition of a timber superstructure would be fatal to them, as they would undoubtedly break, not only at the dowells but in their length. The weight of rail used by him in America, as shewn in Fig. 2, was 75 lbs. per yard, they were 6 feet long, and he never had the slightest difficulty in getting them cast perfectly straight, where an even quality of metal was used.

To the use of iron superstructures there are many objections, viz:—cost, rigidity, great difficulty of working curves without great expense, difficulty of lifting roads for repairs, diversions, &c. In using Burnettised timber there is no fear of decay, is easily and rapidly laid, and capable of working curves, &c., &c., with facility. In all large cities with its gas and water syphons, plugs, &c., great difficulties and expense would be incurred by the use of iron superstructure, which would be entirely obviated by the use of timber, owing to the facility with which timber can be used.

With points and crossings properly constructed no difficulty would exist, as they are, or should be, made rigid castings, without any loose tongues or parts. In America he found them to freeze in winter (when made with a loose tongue), and liable to get out of order at other seasons by vehicles passing over them. This difficulty was entirely obviated by casting them in one piece with chilled points.

It is evident that all the merit of Mr. Curtis' invention is in the wheels, which unquestionably display a considerable amount of ingenuity, not-

withstanding the fact of their requiring *pieces of leather* tacked on to the flanges to prevent them failing in their operation. It will at once be patent that anything of a complicated character is highly objectionable, and where we have to resort to the tacking on of leather straps to tramway wheels, doubly so. This reminds me of an American who was highly indignant, simply, because he could not prevail upon me to use or advocate his "patent anti-friction axle boxes" on my street cars; my reason for not complying was simply that his axle boxes weighed 4 cwt. per set of 4, and the price of which was 100 dollars or £20 per set, without any equivalent advantage.

Mr. Curtis stil adheres to his statement that, with a pair of ordinary cab horses, he can carry 60 or 70 passengers, which, together with the carriage weigh 7 tons, on the rails and off the rails, and depart over the ordinary roads at the rate of 8 miles an hour. This assertion he could not believe; but if what Mr. Curtis states is correct, then the reader contended he had no necessity for a street railway at all, and his invention, carriages, patent wheels, moveable flanges, leather and tacks, at once solve themselves into nothing better than an east-end 3-horse omnibus, and thus we have no necessity for the adoption of Mr. Curtis's plan.

Having no patent for his own system he could not fairly be taxed with personal motives in advocating any particular system, and he could assure every gentleman present that although he spent three years in the perfection and construction of tramways in America, and sacrificed considerable time and money in the enterprise, his only object is to see the best system adopted in this country whenever or wherever it may be carried into effect. This he would say, that in point of simplicity, permanency, and in answering all the requirements of a street railway, without interference with ordinary traffic, he had yet to see a better plan than what is shown in Figs. 1 and 2 and 10, and which he claimed as his own.

What projectors of street railways must confine themselves to in the first instance, is in developing the system on our important suburban thoroughfares, and in roads sufficiently wide to admit of double tracks, for no road or street less in width than 35 feet would be found in practice suitable in crowded cities. In reference to the working of gradients there are none in London or the suburbs offering any serious impediments. Where any gradients occur exceeding an inclination of 1 in 30, he would add another horse, as is done

every day at Holborn Hill. The following data will show what power is gained by the use of iron ways, over ordinary roads :—

Loubat gives us the effective power of a horse on an iron way over that of an ordinary road :—

On a level, as	... ...	8 to 1
On an inclination......1 in 33	... .	$3\frac{1}{4}$ to 1
" " 1 " 16	... ...	$1\frac{3}{4}$ to 1
" " 1 " 12	... ...	$1\frac{1}{4}$ to 1

This, he presumed, would show sufficient advantages for an advocacy of the system of tramways of iron.

The Chairman, in summing up, stated the conclusions arrived at from the discussion were, that street railways could not be introduced into the crowded streets of the metropolis, or in streets of less width than 35 ft.; but that, in agricultural and outlying districts, they would be valuable adjuncts to the existing railroads, and he hoped that, as soon as any of the proposed street railways were in operation, the subject would be again brought before the Society.

SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

COMMITTEE AND OFFICERS FOR 1862.

E. RILEY, *Chairman.*

G. W. ALLAN, 1857.	*Past-Chairmen—Members ex officio.*
R. M. CHRISTIE, 1858.	
H. P. STEPHENSON, 1856 & 1859.	
R. M. ORDISH, 1860.	
J. AMOS, 1861.	

W. T. CARRINGTON.	J. LOUCH.
J. LACEY.	W. PARSEY.
C. L. LIGHT.	F. YOUNG.

A. WILLIAMS, *Hon. Secretary and Treasurer.*

W. H. LEFEUVRE, *Auditor.*

Place of Meeting, Lower Hall, Exeter Hall, Strand.

JANUARY, 1862.

PREMIUMS

FOR 1861.

At the Meeting of the Society, on January 13th, 1862, Premiums of Books were awarded to:—

Perry F. Nursey, for his Paper "On Superheating Steam."

And to

W. H. Stephenson, for his Paper "On Fire Clay Manufactures."

SOCIETY OF ENGINEERS.

RULES AND BYE-LAWS.

Object of Society.

This Society was established for the discussion of scientific and other subjects of general interest.

The Election of Members.

1. The Society shall consist of members of only one class.

Mode of Election.

2. Members to be elected by ballot; one third black balls to exclude.

How to be Proposed.

3. Candidates for membership to be proposed by a member of the Society and recommended by at least three others; the proposer to forward these particulars to the Secretary at least seven days before any ordinary Meeting;

the ballot to take place at the conclusion of such Meeting.

Expulsion of Members.

4. No member to be expelled without the consent of at least three fourths of the members present, or by proxy, at a Special General Meeting, called for such purpose.

Visitors.

5. Members to have the privilege of issuing cards of invitation for two visitors at each Ordinary Meeting.

RULES FOR TH ELECTION AND PROCEEDINGS OF COMMITTEE AND OFFICERS.

Mode of Election.

6. The officers of the Society to be elected at the General Meeting of the members in December, each year, by ballot.

Number of Officers.

7. The officers shall consist of a Committee of seven members, in addition to the Past Chairmen of Committees, and Honorary Secretary and Treasurer, who shall be members ex officio. The Past Chairmen to be limited to six, to retire by seniority, but to be eligible for re-election on the Committee.

Election of Auditor.

8. A member (not being one of the Committee) to be elected as Auditor, who shall make his report at the first Ordinary Meeting in each year.

Quorum.

9. Four members to be a quorum; the Chairman to have the casting vote.

Election of Chairman.

10. The Committee to elect their Chairman by ballot, who shall be Chairman of all Meetings throughout the year.

Nomination of Deputy-Chairman.

11. In the absence of the Chairman at any Meeting, a Deputy shall be nominated by the Committee.

Management of Funds.

12. The Committee shall have the sole management of the funds, and the entire superintendence of the Society.

Selection of Subject for Discussion.

13. The Committee shall select the subjects and papers to be read and discussed at the Ordinary Meetings. Members wishing to read a paper, or who wish to have a particular subject discussed, must notify the same to the Committee.

Meeting of Committee.

14. A Special Meeting of the Committee shall be called on the requisition of three of its members.

Retirement of Committee.

15. The Committee to retire each year, but to be eligible for re-election.

List of New Officers.

16. The Committee resigning office shall prepare a list of proposed new officers, which shall be sent to each member with the notice of the General Meeting.

Members wishing to be Elected on Committee.

17. Any member offering himself for election on the Committee, must give in his name to the Committee on or before the ordinary meeting in November. The name of such member shall be appended to the list proposed by the Committee.

Election of Committee.

18. Members who do not attend the General Meeting should forward the above-named list to the Honorary Secretary, with such alteration in the names as they desire, which, with those from the members present, shall be handed to two scrutineers appointed

by the Chairman, who shall ascertain the number of votes obtained by each member; and the Chairman shall make known the result to the meeting.

Equality of Votes. **19.** In case two or more members have the same number of votes, the election of such members to be decided by lot.

Election of Hon. Secretary and Treasurer. **20.** The Honorary Secretary and Treasurer to be elected by the members of the Society, and to be nominated in the list of officers proposed by the Committee for the year ensuing.

Custody of Funds and Accounts. **21.** The Honorary Secretary and Treasurer shall keep the funds and accounts of the Society, which shall be open for the inspection of any member.

Subscriptions, &c.

Entrance Fee. **22.** An entrance fee of ten shillings to be paid by members on election.

Annual Subscription. **23.** The annual subscriptions to be ten shillings, and paid in advance. They are due on the first day of January in each year.

Members Joining. **24.** Any member joining the Society shall pay his entrance fee, and annual subscription, which shall be considered as paid only to the 31st of December ensuing.

Disqualification to Vote. **25.** Members whose subscriptions are unpaid are not qualified to vote.

Subscriptions in arrear. **26.** Members whose subscriptions are in arrear for three years, to be struck off the register of the Society.

Meetings of the Society.

Ordinary Meetings. **27.** The ordinary Meetings shall be held on the second Monday in January, and the first Monday in February, March, April, May, June, September, October, November, and December, unless otherwise specially ordered by the Committee. The Chair to be taken at 7 o'clock, p.m.

Special General Meeting. **28.** A Special General Meeting of the Society shall be called on the requisition of eight of its members, who shall send to the

Committee the resolutions to be proposed by them at such meeting.

Management of Discussion. **29.** The Chairman to have the power of directing the manner of discussion.

General Meeting. **30.** There shall be a General Meeting held within the first fortnight of December in each year, to elect the officers of the Society for the ensuing year.

Voting by Proxy. **31.** Members are entitled to vote by proxy.

Notice of Meetings. **32.** The Honorary Secretary shall write to every member at least four days before each ordinary Meeting, naming the date of the same, the subject of the Paper, and by whom to be read; likewise the names of Candidates for Membership, and by whom proposed.

Order of Business. **33.** The Honorary Secretary shall commence the proceedings of each meeting by reading the minutes of the one preceding, the abstract of the paper read, with notes of the discussion at the previous meeting, and the names of the gentlemen proposed for election.

Premiums for Papers. **34.** Premiums in Books, not exceeding the value of Six Pounds, will be given annually for the best Papers read during the previous year. The decision to be left to the Committee, who are disqualified from receiving premiums.

Publication of Papers. **35.** After each Paper is read, the Committee are to decide whether it would be desirable to publish it, and, on obtaining the author's consent, are to arrange with the Editor of a Scientific Journal to publish the whole or part of the same.

Alteration of Rules. **36.** No alteration to be made in the above Rules and Bye-Laws without the sanction of a Special Meeting called for that purpose.

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Elected.	
1858	C. D. Abel
1856	A. Aird
1856	C. Aird
1855	J. Aird
1860	J. P. Adkins
1854	G. W. Allan
1859	J. Allen
1857	J. Amos
1860	G. Anderson
1859	W. J. Arliss
1861	J. Ashby
1859	J. Ashdown
1861	J. Ashlin
1861	J. P. Ashton
1860	E. Aydon
1861	W. B. Backshell
1859	J. D. Baldry
1860	H. T. Balfour
1860	C. Barnard
1860	E. B. Barnard
1861	J. C. Bayley
1860	J. Beardmore
1860	W. Benbow
1854	W. Binns
1859	C. Botten
1861	R. H. Boyce
1859	J. Boys
1858	R. Brass
1861	J. Brenchly
1859	E. W. Briscoe
1860	R. Broad
1854	G. Broaderick
1856	Lieut. Broaderick, R.N.
1859	J. B. Brown
1861	W. H. Browne

Elected.	
1858	A. G. Browning
1857	C. E. Browning
1859	F. W. Bryant
1856	C. Burn
1859	G. Bush
1854	D. Campbell
1860	G. Campion
1859	J. Carrick
1858	W. T. Carrington
1859	L. B. Chemin
1854	R. M. Christie
1860	J. G. Clarke
1861	F. J. Clowes
1859	F. Colyer
1860	H. Coombs
1855	C. Copland
1860	J. Copland
1858	C. Cousins
1858	J. A. Cowen
1860	W. G. Cox
1861	H. C. Coulthard
1861	J. Croome
1859	C. Cubitt
1859	J. G. Davenport
1859	L. E. Davies
1858	J. Dewdney
1859	B. Donkin
1861	J. Donkin
1859	R. Dyson
1860	J. A. Eaton
1859	P. Edinger
1858	E. Edwards
1860	E. J. Eliot
1858	J. Elliott
1860	J. Evans

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Continued.

Elected.		Elected.	
1860	C. Farrand	1861	R. Howson
1858	F.W.Featherstonhaugh	1859	J. Humphreys
1861	E. Field	1861	C. Hunter
1859	H. Finlay	1860	J. T. Hurst
1859	L. Flowers	1859	J. Hutcheson
1856	J. Forbes	1860	F. M. Hyam
1859	C. Gandon	1859	F. Ingham
1860	T. Gandy	1858	T. G. Iveson
1861	L. Golla	1860	P. A. Jeffcock
1859	G. Gordon	1861	F. Johnson
1859	J. Glynn	1860	G. Johnstone
1859	F. B. Gray	1858	A. R. Jones
1854	J. W. Gray	1860	C. Jones
1861	H. Greaves	1860	H. Jones
1861	T. Grove	1861	W. Jones
1860	J. C. Grover	1860	J. Keddall
1858	J. Hadley	1855	J. Keith
1861	J. Halford	1861	C. F. Kell
1860	G. Hall	1859	B. D. Kershaw
1860	F. Hallett	1859	J. T. Kershaw
1860	R. Harris	1854	R. King
1855	G. Harrison	1861	E. B. Kirton
1861	G. P. Hawkes	1860	W. E. Kocks
1861	J. T. Heggie	1858	J. Lacy
1861	H. Head	1859	R. Laing
1858	T. Hendry	1861	B. Latham
1859	F. Herring	1861	J. Laurie
1861	J. A. C. Hewett	1858	W. H. LeFeuvre
1860	E. H. Hilliar	1858	E. J. Leonard
1860	J. S. Hobbs	1860	J. Leonard
1859	J. Hogg	1856	C. J. Light
1861	G. E. Hollest	1859	C. L. Light
1860	F. Hope	1860	F. Littlewood
1860	F. F. Hope	1859	G. Livesay
1859	C. Horsley	1859	J. Lockwood

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Continued.

Elected.		Elected.	
1860	E. H. Long	1861	J. E. Pringle
1861	A. Longbotham	1856	J. Quick, Jun.
1856	J. Louch	1860	H. Raincock
1858	B. Martin	1859	G. Rait
1861	B. B. Marshall	1859	F. C. Reynolds
1860	M. G. Martinez	1860	E. Riley
1860	W. G. McGeorge	1860	C. Robinson
1859	W. P. Miles	1859	R. A. Rumble
1859	G. Molesworth	1858	T. W. Rumble
1858	E. H. Moore	1861	C. Sanderson
1859	W. Moore	1860	G. Shaw
1861	J. F. Morgan	1860	G. P. Shearwood
1860	F. Morris	1854	G. Shillito
1859	W. Morris	1860	D. Siebe
1860	W. Morris	1859	E. Simpson
1856	W. T. Morrison	1859	A. B. Smith
1857	F. R. Moultrie	1859	G. F. Smith
1859	G. Muriel	1860	H. Smith
1861	G. B. Nethersole	1860	H. G. Smith
1861	J. W. Newton	1859	R. M. Smith
1858	P. F. Nursey	1858	S. Smith
1860	J. H. Ohren	1854	W. H. Smith
1856	M. Ohren	1858	W. Snell
1861	E. Olander	1859	A. E. Stephenson
1860	D. A. Onslow	1854	H. P. Stephenson
1859	T. Orchard	1857	W. H. Stephenson
1857	R. M. Ordish	1859	C. W. Stocker
1856	T. Ormiston	1861	A. S. Stride
1859	J. B. Paddon	1861	W. Sugg.
1859	G. G. Page	1859	W. P. Sutherland
1858	W. Parsey	1861	L. Swann
1860	E. Pemell	1861	W. H. Thomas
1859	D. Pigeon	1861	H. L. Thompson
1859	B. L. F. Potts	1860	A. Thorn
1859	J. T. Potts	1860	P. Thorn

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Continued.

Elected.		Elected.	
1860	W. W. Tothill	1860	A. Wilson
1859	H. H. Treppas	1860	C. G. Wilson
1861	G. Trickett	1861	G. Wilton
1861	H. Vavasseur	1858	F. Wise
1858	G. Waller	1861	W. H Wood
1861	A. E. Walton	1858	E. I. Woodhead
1860	D. Watson	1861	J. Wright
1861	S. Watson	1861	A. F. Yarrow
1859	W. H. Webb	1859	F. Young
1859	E. J. Whitaker	1859	J. L. H. Young
1860	J. Willcock	1861	J. Young
1855	A. Williams		

SUBSCRIPTION ACCOUNT, 1861.

	£	s.	d.		£	s.	d.
Arrears due on 1st January, 1861	59	0	0	Received in advance in 1860 for 1861	2	10	0
Subscriptions due from 236 members at 10/	118	0	0	„ for Subscriptions and Arrears	97	0	0
Admission Fees due from 19 members at 10/	9	10	0	„ for Admission Fees	7	10	0
Subscriptions for 1862-3 being paid in advance	2	0	0	Written off in accordance with Rule 26	25	10	0
				Received in advance for 1862-3	2	0	0
				Balance Arrears due	54	0	0
	£188	10	0		£188	10	0

RECEIPTS AND EXPENDITURE FOR 1861.

	£	s.	d.	£	s.	d.		£	s.	d.
Balance in hand January 1st, 1861				6	13	6	By Rent of Hall	23	2	0
Total amount received for Subscriptions	99	10	0				„ Advertisements	12	8	0
Deduct received in advance in 1860	2	10	0				„ Engineer Journal	1	7	0
	97	0	0	97	0	0	„ Short-hand Writer	3	13	6
Received for Admission Fees				7	10	0	„ Stationery	13	6	3
„ for Conversazione Tickets				0	12	6	„ Postage	12	19	1
Received in advance for 1862-3				2	0	0	„ Wages, Fees, &c.	9	0	0
							„ Premiums	6	0	0
							„ Expenses of Conversazione	21	15	3
							„ Sundries	0	16	4
							„ Balance Cash in hand	9	8	7
				£113	16	0		£113	16	0

Examined and found correct.

Signed, C. L. LIGHT, W. PARSEY, } *Finance Committee.*
W. H. LEFEUVRE, *Auditor.*

March 4th, 1861.

JAMES AMOS IN THE CHAIR.

ON FIRE-CLAY MANUFACTURES.

BY W. H. STEPHENSON.

Fire-clay, and its manufactures, are every day becoming more generally understood, and taking their place as an important branch of national and commercial enterprise.

Fire-clay is found in Wales, Scotland, Stourbridge, Leeds, Dorset, Surrey, and Newcastle; the relative merits of which are best shown by their commercial value. The author's remarks were mainly confined to the nature, manufacture, and use of the Newcastle clay, with which he was more intimately acquainted.

Among the various deposits which have succeeded the formation of the primitive rocks upon the surface of the globe, there are certain earthy strata of very considerable extent composed chiefly of silica and alumina, partly in combination, and partly in mere mechanical mixture with other less prominent and essential ingredients. These strata are characterised by the very minute state of division of their particles, and their want of firm connection or solidity. It is to this peculiar structure that the most valuable property of clay must be ascribed—that is, its plasticity, or the property of forming dough with water, sufficiently soft to take the most delicate impression from a mould, and so deficient in elasticity that even the slightest indentation is lasting and persistent.

By far the greater number of clays are so intermingled with substances foreign to them in their original localities, or have been primarily derived from such compound species of rock, or, lastly, have been so very far removed by the agency of water from the sources of their different constituents, that it is next to impossible to trace back the course of their formation to its very commencement; although the clays may be viewed in general as the remains of certain rocks which have been decomposed by various agents, chiefly atmospheric, which have, in a word, been weathered; yet there are few cases in which the production of clay has occurred in the immediate locality of the rock whence it is derived, and in such a simple manner as to enable its origin

to be traced in all particulars, and established indubitably by chemical facts.

The most prominent physical properties of clay are its plasticity and behaviour when exposed to heat. By simple drying, at a temperature far below red heat, its particles collapse, the primary pores become contracted, and a very much more dense mass is obtained, which becomes so hard that it will no longer take impressions, although it is still sufficiently soft to be cut with a knife, and when treated with water is again converted into clay with the ordinary properties.

Exposed to the most intense heat that can be artificially produced, clay refuses to become liquid, and acquires at most a slight degree of flexibility. Its particles then cohere so strongly together that the burnt mass is hard and sonorous, although still porous enough to absorb water with avidity. Although it no longer falls to pieces, but retains its connected form, it will easily be conceived that the nature of clay must be very much modified by an admixture of foreign matters possessing other properties. These foreign matters may either be constituted of undecomposed detritus of the rocks from which the clay itself derives its origin, or of others which do not belong to the class of substances which yield clay by decomposition. The character of these foreign admixtures causes great variation in the nature of the different clays, and gives rise to the various denominations by which they are known. The ingredients which most affect the quality of the clay are sand, iron, lime, and magnesia.

The plasticity of clay diminishes with the amount of any one of these substances which it contains, as they are not plastic.

The quality is affected in the most marked manner by sand, somewhat less by lime, and very little by oxide of iron. When clay contains iron and lime the action of heat upon it is very different: the silica, alumina, lime, and iron then form together a mixture similar to that employed in the manufacture of bottle glass, which melts in the fire with more or less ease, according as it contains much or little of the two latter ingredients. Magnesia exerts less influence upon the character of the clay; the more quartz and silica enter into the composition of the clay the less easy will it be of fusion, and an

excess of iron or lime can be corrected by a large quantity of this ingredient.

Fire-clay is commonly found in the coal measures, at a great depth from the surface, but it not unfrequently happens that it lies on the top. The author's experience was with clay at some considerable depth, and lying (at Throckley, Newcastle-upon-Tyne) immediately underneath the coal formation; its thickness varies according to circumstances, in some places 3 ft., and in others reduced to 18 in. As a rule it is very strong and hard, and cannot be worked to advantage without the aid of gunpowder. It would be needless to recapitulate the ordinary working of a coal mine; but suffice it that the clay, on being raised to the surface, is laid out in long parallel heaps, say 20 ft. high, being 20 ft. wide at the bottom, and tapering to 5 ft. at the top. A series of ridges is thus formed, purposely, however, in order to collect as much rain and snow as possible, which, combined with the direct action of the atmosphere, soon reduces that which was at one time hard and retentive, to a soft, comparatively plastic state. Differences of opinion exists among manufacturers as to the policy of adopting this system, inasmuch as to carry it out fully a very large capital is necessary, and which for the time being lies dormant.

The sole advantage accruing in keeping so large a stock is, that it is more easily pulverised and reduced to powder, thereby causing a considerable saving in engine power, labour, and expense. To carry out this method to its fullest extent no clay ought to be used until it has been exposed to the action of the elements for at least two years. It might not be always convenient to lay out so much capital in dead stock (the establishment with which the writer is connected never has less than 20,000 to 25,000 tons weathering, every ton of which has cost 2s. 6d.); therefore it is best to allow each manufacturer to consult his own interest. After the clay is brought to the works the first process is that of grinding—the most approved plan is that of two large stones, say 10 ft. in diameter, and 20 in. wide, hooped all round with iron, and revolving slowly on a cast-iron pan, or bed-plate, which in some works is also made to revolve very slowly the contrary way to the stones. The rough clay from the pit being conveniently placed for the workman, is cast under the edge stones, when it is ground to a

coarse powder, which falls through an open grating in the centre of the bed-plate, whence it is lifted in the sifting cylinder by an endless chain of buckets. The clay, as it passes down the cylinder, is separated into two parcels, the coarse, or that which is too large to admit of its being passed through the meshes of the cylinder is returned by a long wooden spout to the mill, where it a second time is ground, whilst the fine particles are received into an endless belt composed of glazed sack cloth, and conveyed into the mixing pan, or pug-mill.

Up till within the last few years the process of pugging was performed entirely by the feet. A great advantage is gained by treading with the naked feet, as the workmen is enabled to feel whether any stones are mixed with the clay, in which case he removes them; more water was then poured on the clay if necessary, and then again fresh clay, until the whole becomes so stiff as to impede the action of the feet. Wherever there is an extensive bed of fire-clay, and a regular and considerable demand for bricks, &c., where permenent brick works can be established, and more costly and practicable arrangements are necessary (as in the Newcastle district), the preparation of the clay is carried on with much greater care and more expense, and generally with the assistance of machinery.

Some manufacturers prefer allowing the pugged clay to lie and *sweat* for a few days in a dark place, thereby giving greater ease and facility in working, the clay being rendered of a more plastic nature by the delay. Others remove it immediately from the pug-mill to be moulded into bricks, retorts, &c.

Brick moulds are made of various materials, some of brass, cast in four pieces and rivetted together, others of sheet iron cased with wood in the two longest sides. Iron moulds are *sanded* but not wetted. Copper moulds are an improvement on the iron, as they require neither sanding nor wetting, and do not rust; they, however, are expensive, and do not last long, as the edges wear down very fast.

The cost of moulding bricks bears so small a proportion to the total cost, that it is questionable whether the application of machinery for this purpose in small works would effect any ultimate saving; numerous inventions have been patented, but few of them can be said to have proved successful.

The moulding operation in the ordinary brickworks is simpler than is the case with any other kind of clay ware.

The workman is supplied with a stock of clay (from the pug-mill) by his side, a table or bench before him, and two boys or helpers. The mould is larger in proportion than the finished brick, owing to the contraction of the clay in drying and burning; this, of course, varies under different circumstances, the tougher and finer the clay the greater the contraction, and *vice versa;* in general, 1 in. to the foot is the calculation for contraction, and the moulds must be made accordingly.

The usual size of a brick is 9 in. long, 4½ in. broad, and 2½ in. thick.

The mould itself only makes the four narrow sides of the brick, the one broad surface being produced by the table which supports the mould, the other by a straight piece of wood, with which the workman removes away the excess of clay, by drawing it straight along the upper edge of the mould. To prevent the clay adhering to the mould, it is from time to time damped with water, which causes the moulded brick to separate from the mould without bending or loss of time. The operation is conducted as follows:—The workman throws a lump of clay with great force into the mould before him; the mass, which has become flattened by the shock, is forced into the corners by one or two rapid strokes with the hand, and that which projects beyond the mould is taken away with the flat board. By a sudden and peculiar twist of both hands, the workman deposits the brick from the mould on to a thin board previously placed before him for the purpose; one of the boys in attendance immediately places another similar board on the top of the newly-made brick, and thus carries it away between these two boards. Meanwhile another brick is made as described, and thus the process continues during the hours of labour. The bricks are placed in long rows edgeways on the dry flats, a space equal to the thickness of the board, say, ¼ in. being left between each brick, in order to give vent to the steam generated in drying.

The drying sheds or flats consist of long floors, say 90 ft. by 30 ft., with flues running the whole extent of the building. It is desirable not to have the length of these flues more than, say,

40 ft., in order to ensure a good draught without any additional coals being used.

In most manufactories these drying flats are so constructed that there is ample room or accomodation for two days' work; in this case the moulders are never stopped, and are not required to remove their tables or benches from place to place. From thirty-six to forty-eight hours is calculated quite sufficient for drying bricks; so that while the moulder and his boys are depositing bricks on one part of the flat a gang of men and boys are engaged in clearing away the bricks from another part.

The number of bricks which a workman can mould in a day of ten hours is always very considerable, but depends very much upon the ability and strength of the moulder. With clay in good order a skilled workman can make 2,000 to 2,500 marketable bricks in a day: thus taking 2,000 bricks as a fair average day's work, and calculating 3s. 6d. for the man, and say 1s. 6d. for two boys, we have 5s. per diem, or 2s. 6d. for 1,000, the cost in moulding, which is about the price usually paid. The mere moulding of bricks is consequently a very cheap process. The cheapness and simplicity of the hand process renders it difficult to devise machinery that shall supersede it; the produce of a moulder is nearly equal to that of a machine, and the prime cost and expense of keeping machinery in order is only likely to be remunerative where circumstances are very favourable, and a great outlay of capital is desirable. These combined circumstances seldom occur together.

The interest of capital, the necessity of keeping a machine constantly at work, and the cost of the motive power which such machines require, demand a constant and very extensive market for the produce.

It may, however, be interesting to notice the principle upon which the machines are constructed.

I. *Machines with Actual Moulds Similar to Hand Moulds.*

A single mould is used, which is filled, smoothed, and moulded by machinery. The mould is first brought under the clay machine to be filled, after which it passes under that part of the machine which presses the clay into the mould, and, lastly, is deposited exactly above a piston which from below raises the brick out of the mould.

II. *Machines in which the Moulding is Performed by Several Moulds.*

These are arranged upon a revolving plate, or upon the curved surface of a cylinder. In the first case the motion is either backwards and forwards, or rotatory round a perpendicular axis; in the second case it is rotatory round a horizontal axis. In Forsyth's machine, for instance, a steam piston presses the clay contained in a cylinder on to a movable mould frame, which forms the bottom of the cylinder. This mould frame is divided into a number of quadrangular compartments (which are the brick moulds) and is moved backwards and forwards, so that the half of the moulds are alternately brought under the piston and filled, while the other half are discharged on a drying board by a part of the apparatus which pushes the bricks out of the moulds.

III. *Machines which produce a continuous Strip or Band of Clay, and subsequently cut it into separate Bricks.*

A strip of this kind forms a parallelopipedon of indefinite length, the thickness of which corresponds to the thickness of the bricks, and its width to their breadth. When therefore a piece of this strip is cut off of the length of a brick, it will correspond exactly with a brick in dimensions. The production of the band of clay in this machine is similar to that practised in manufacturing maccaroni, or to the process of wire-drawing, *i.e.*, the clay is delivered from the clay mill into a cylinder, the piston of which forcibly presses the contents through an aperture of the dimensions stated above; the strip thus produced passes through rollers which improve its shape, and is then received upon a horizontal surface, where it is cut into lengths by wires moving in a vertical direction (up and down).

The operation of drying the green bricks requires great care and attention, as much depends upon the manner in which they are got into the kiln. The great point to be aimed at is to allow each brick to dry uniformly from the face to the heart, and thus to present a smooth even surface throughout.

After remaining on the flats till sufficiently hard and dry, they are built up in the kilns, when the operation of burning commences. Bricks are burnt, as may easily be conceived, in a variety of ways. Cost and custom must be taken into consideration. There are many

ways of constructing kilns, and scarcely any two are exactly alike. The circular kiln, or cupola, is domed over at the top, whence its name is derived. The fire-holes are merely openings left in the thickness of the wall, and are protected from the wind by a wall built round the kiln at a sufficient distance to allow the fireman room to tend the flues. The cupolas are used in Staffordshire and the neighbourhood, and the heat employed in them is very great.

The common rectangular kiln, as used in the Newcastle district, is formed by building four walls enclosing a rectangular space, with a narrow door-way at one end and also apertures or arches for firing at the same end with the door, the flues being placed at the opposite end and leading into the chimney.

The usual method of placing bricks in the kiln is to cross them, leaving spaces between each brick for the passage of the heat; but there are objections to this, as many bricks show a different colour where they have been most exposed to the heat.

In burning bricks that require to be of even colour, this is guarded against by placing them exactly on each other. On first lighting a kiln, the heat is got up gently that the moisture in the bricks may be gradually evaporated.

When the bricks are thoroughly dried, which is known by the steam ceasing to rise, the fires are made fiercer; as the heat increases the fire holes are covered with iron lids or doors to check the draft, and when the burning is completed they are plastered over to exclude the air, and the fires are allowed to go out. After this the kiln is, or ought to be, allowed to cool very gradually, as the soundness and quality of the bricks are much injured by opening the kiln too soon. Under ordinary circumstances a kiln of fire bricks, containing, say, 12,000 bricks, requires from the commencement about five days for the burning process, and during that time will consume 12 to 15 tons of coals.

As before stated, the relative merits and value of fire bricks depend upon their fire resisting qualities, and hence depend upon the proportion of silica they contain.

In an analysis of several kinds of Newcastle clay, Dr. Richardson found—

Nos.	1	2	3	4	5	6	7
Silica	51·10	47·35	48·55	51·11	71·28	83·29	69·25
Alumina . . .	31·35	29·50	30·25	30·40	17·75	8·10	17·90
Oxide of Iron	4·63	9·13	4·06	4·91	2·43	1·88	2·97
Lime	1·46	1·34	1·66	1·76			
Magnesia . . .	1·54	0·71	1·91	trace	2·30	2·99	1·30
Water and Organic Matter	10·47	12·01	10·67	12·29	6·24	3·64	7·58

whilst the amount of silica in No. 6 is to the total amount of the bases as 100: 16 in No. 2 it is as 100: 85. These clays are mixed in different proportions, according to the object of the manufacturer.

The price varies according to quality, and averages, say, 40s. to 50s. per 1,000 in the Newcastle district. When, therefore, it is desirable to procure a first-class article, a chemical analysis, although it cannot supersede an actual trial, may be of the greatest service, as the clays seldom or never come up to what is required of them, and only acquire the requisite properties by certain additions, and the choice of these additions must, in the first instance, be guided by the results of the chemical analysis; such additions are absolutely necessary, as fire-clay must not only be infusible in the fire, but must likewise not be subject to crack and fly. These properties are most important. The chief cause of the cracking, or the contraction of the clay, must therefore be lessened by the addition of substances, which do not shrink themselves, and, on the other hand, do not impair the refractory nature of the clay.

Pure sand and previously burnt fire-clay are the substances most commonly and appropriately used.

The process of fire-clay retort making on the most approved principle, and as at present practised in the Newcastle district, was then explained.

Referring to the period when the fire-clay has been drawn from the mine and undergone the process of weathering, that which is intended for retorts has been kept separate for that purpose, while greater care and attention has been bestowed on it, in order to pick out any pieces of coal or iron with which it may have been associated. This, although seemingly an insignificant, is a very important part of the manufacture,

inasmuch as a very small piece or particle of ironstone is sufficient to damage and spoil a whole retort, and thereby occasion considerable loss.

The clay having been thus thoroughly examined and approved, is next ground in a similar manner to ordinary fire brick clay, excepting that the particles are not ground so fine (the average size of the meshes through which the clay passes for bricks is, say 5×6 to the inch, whereas for retorts it is as large as 3×4 to the inch), and in order to render the retorts porous, a proportion of coke or sawdust, say $\frac{1}{4}$ to $\frac{1}{3}$ the weight of the whole is added to the fire-clay, and mixed up with it, both in the grinding and pugging process. The pug-mill, through which this retort clay passes, is generally longer and wider than the ordinary brick clay pug-mill; or, instead of this, it is not unusual to pass the clay through two pug-mills, the one delivering into the other, so as to insure the clay being well worked and of a proper consistency.

The manufacture of clay retorts was formerly carried on by machinery, but now the same objection may be said to exist against this method, as we have stated to be the case with regard to machinery for brickmaking. The result has, therefore, been that retort-making by hand has now become the rule, and by machinery the very rare exception.

The hand building is performed by small lumps of clay being pressed against the side of a mould or drum the required shape, and this continued till a height of 8 in. or 10 in. is obtained, the walls being gradually built up according to two wooden guides, the one of which indicates the thickness, say $2\frac{1}{2}$ in. to 3 in.—the other the outward shape of the retort.

Some clays are more plastic than others, and will, consequently, bear a higher or longer building, but in general 9 in. are sufficient at once, in order to ensure soundness and firmness. This process of building is continued every day, or as often as necessary, till any length of retort is obtained, the top end always being kept perfectly moist, to guarantee perfect adhesion throughout the whole. The flats or sheds in which these retorts are made, are constructed in like manner to the brick flats, excepting that more height is allowed from the level of the

floor to the joists, to contain the longest retorts. Fires are constantly kept burning under the floor on which the retorts are being built, and this process of drying is perhaps one of the most important of the manufacture. If not carefully and properly dried, cracks will show all over the surface, the colour of the fracture will not be uniform, and the retorts essentially bad.

It was stated that coke and sawdust were mixed with the clay, in order to make the whole mass porous. To provide against the porosity of the retorts causing a loss of gas, a composition or mixture, composed of about equal parts of unburnt and calcined fire-clay finely pulverised, with the addition of as much water as renders it a consistency of thick *paste* is applied day by day to the internal and external surfaces of the retorts, and well worked in (by the hand) to the body of the retort: thus an even, smooth, and unbroken surface, free from cracks and flaws, is produced, and the retort presents an uniform appearance throughout.

The burning of the retorts requires much care and attention, and generally continues for a period of ten to twelve days. The retorts being placed vertically on rows of bricks on the bottom of the kiln, the great desideratum is to procure a steady draft, the exclusion of atmospheric air, and a gradually progressive heat.

Opinions differ very widely as to the best shape of clay retorts, the circular, oval, or elliptical, and ⌓, being those commonly advocated and in use, while the egg-shaped, or combination of round and oval, and the round curved ⬭ have each their supporters. In the leading metropolitan works the 15 in. round, and 21 in. × 15 in. oval, in settings of five and seven retorts in a bench, appear to be in favour; these retorts being from 18 ft. 6 in. to 20 ft. in length (open throughout, and charged at each end), are constructed in three or four pieces to suit convenience.

An experienced retort maker can manage twenty-five to twenty-eight retorts at once, and taking 9 in. as the average daily building to each, moulds, consequently, say, 18 ft. to 20 ft. per day.

The comparative merits of clay and iron retorts is a subject which has attracted much attention from the gas engineering profession during the past few years. The results of numerous practical trials, comparing

their relative durability, economy, and carbonising power, have from time to time appeared in the various serials devoted to the gas-light interest, and many facts worthy of attention have been elicited by the controversy respecting their comparative excellence. It may seem a matter of much surprise to those unacquainted with the details of these practical essays, that a substance apparently so friable and brittle in its nature as clay should have superseded cast-iron to a great extent, and received the highest encomiums from nearly every responsible source. Yet such has been the case, and this important reform, which but a few years ago met with many obstructions, in having to withstand a rigorous prejudice, has lately been gaining ground with great rapidity, and promises ere long to meet with universal approbation.

The introduction of clay retorts seems to be due to Mr. Grafton, who as early as the year 1820, took out a patent in England for their use. His retorts were at first *square*, but soon after were altered to the shape of a broad shallow ⌓, and were constructed in sections of about 16 in. in length. These retorts were 5 ft. wide, and 18 in. high, being 7 ft. long, resembling an oven in their general contour. This shape was used for many years in some of the provincial works of Great Britain, and are perhaps still employed to some extent, although they have been generally replaced by the oval, circular, and common ⌓ shaped retort.

The Managers of the gasworks of Scotland were among the first to appreciate the value of clay retorts, and their use in now almost universal in that country. They were then employed for a considerable period before their general introduction into England, where, as their superiority became more generally known, they were gradually adopted, and at this moment the proportion of iron and clay retorts in operation in the whole of Great Britain greatly preponderates in favour of the clay. He did not like to be too sanguine or positive in his predictions as to the future, and being himself interested to a large extent in the manufacture of clay retorts, perhaps he might be excused in agreeing with Mr. R. M. Christie, late chairman of this Society, who, in his able article on the "Relative Merits of Clay and Iron Retorts," in the *Journal of Gas Lighting*, April, 1857 (and since extended in a separate pamphlet), says that in a short time, should we wish to see iron retorts, we shall have to pay a visit to the British Museum.

The superior qualities claimed for clay retorts over those made of iron are as follow:—Their cost is less than iron; they are more durable; they have more carbonising power, and produce a greater quantity of gas. There are some parties who still advocate the use of iron retorts, and who, of course, will not admit these claims, but those who have adopted the clay retorts are firm in their belief that all of the qualities above mentioned are amply sustained; as to the first cost of a retort, it is quite unnecessary to attempt to prove the superior economy of clay over iron, inasmuch as to all who are in the least familiar with the subject it must be at once apparent.

The durability of a retort is a subject of great importance in an economical aspect, and unless this is attentively studied and abundantly demonstrated, no opinion can be regarded as conclusive. But, as regards the relative durability of clay and iron retorts, the results of the trials have satisfactorily proved the superiority of clay. According to Mr. Christie, the average duration of iron retorts, as worked in England, is ten months; whereas, in London, some clay retorts have been set and in use for four, five, and six years, and those which have been used two and a half to three years may be seen at almost any works where they are employed. This, however, may be a rather exaggerated statement, although a duration of two years has commonly been obtained. At the South Metropolitan Works, in London, seventeen months have been considered a fair duration for clay retorts, each one having produced 1,800,000 ft. of gas; the expenditure of coal being no greater than that of iron retorts.

The paper has hitherto been confined exclusively to the manufacture of bricks and retorts made from fire-clay, while several other very important articles, have been passed over the limits assigned to this paper being much too small to admit of doing more than simply mentioning them. We have now glazed and plain sanitary and chemical pipes made in great abundance, also chimney tops, glass house pots, and ornamental vases, together with every description of lumps and tiles usually required for the erection of iron, chemical, and gas works.

The stoneware manufacture is now principally located in Lambeth, Glasgow, Leeds, and the Staffordshire potteries. Salt glazed stoneware

has long been extensively used for the apparatus required for manufacturing muriatic, nitric, and oxalic acids, &c., on a large scale, and for jars and bottles to contain acids, spirits, oils, and other penetrating and corrosive liquids. It is also largely employed for drain and chimney pipes of various diameters, for which purpose it is admirably adapted, being perfectly imperishable, impervious, and capable of being highly glazed inside, thus greatly facilitating the necessary flushings and cleansings of the flues and drains. It is also extensively used for the insulators for the electric telegraphs on all the railways.

Stone bricks manufactured at Neath, in Glamorganshire, are possessed of very peculiar properties. The materials of which this brick is composed are brought from a quarry in the neighbourhood. They are very coarse, being subjected to a very rude crushing operation under an edge-stone, and from the size of the pieces it is impossible to mould by the hand.

There are three qualities which are mixed together with a little water, so as to give the mass some coherence, and in this state it is compressed by a machine into a mould.

The brick which results is treated in the ordinary way; but it resists a much greater heat than either the Stourbridge, Leeds, or Newcastle fire-clay, expands much more by heat, and does not contract to its original dimensions. Owing to this latter property it has been found very valuable in constructing furnaces, more particularly the arches of the reverbatory furnaces employed in the smelting of copper ore. The proportion of silica in this clay is 90 to 95 per cent., and the bricks may therefore be said to be siliceous, or stone bricks.

There is no doubt that the subject of fire-clay and its appliances generally, is one which will every day become better understood, and it is also very evident that its manufacture will gradually assume a higher and more important position among scientific enterprise. It may be said to be still in its infancy, and who shall predict the results which may hereafter accrue from its development.

Some few years ago clay retorts for gas making had not been introduced, and the manufacture of fire goods was confined to a very small compass. Now, how is the aspect of affairs changed! Gentlemen of

ability, enterprise, and wealth are going earnestly into the trade—experiments are being made to ascertain the best and cheapest mode and method of manufacture.

DISCUSSION.

Mr. Riley said he had made some special investigations on the properties of various descriptions of fire-clay in use at the Dowlais Iron Works, and came to the conclusion that the quality of the clay depended on the presence of a high per-centage of silica. It was a well known fact, that the best material for standing heat and fluxing action, is the ordinary conglomerate and some sand stones of the coal measures. These latter being used for making the Dinas brick, which is, in fact, nearly pure sand, mixed with 1 or 2 per cent. of lime to frit it together. He had had much experience in the Bessemer process, in which he believed there was a greater fluxing action, and a higher temperature produced than in any other manufacturing process. He had seen an ordinary Welsh brick completely fluxed away in about twenty minutes, and the only material that is proved at all to stand is the powdered sand stone, known as Ganister. The Dinas bricks did not stand fluxing action well, but were adapted for the roofs of coke ovens, where they stood when other bricks failed. He thought this was due to the bricks being porous, and not solid, and that they might be improved by making them more homogeneous, by grinding finer and using greater pressure.

In some practical experiments made at the above works, it was found that the bricks made from the veins of clay which contained the highest per-centage of silica stood the longest time in the puddling furnaces. It was always found that bricks wore away at the clay-joints. This, he thought, was due to the clay not having been submitted to the pressure that had been used in making the bricks, and this pointed out the necessity of having solid bricks, or bricks that had been submitted to great pressure, and made as dense as possible. One great advantage of the Dinas brick was, that it expanded on heating, and thus closed the joints, although this brick is not well adapted for sudden changes of temperature, and this is one reason why they stand so well in coke ovens.

Mr. H. P. Stephenson was of opinion that clay retorts in large works were decidedly advantageous, in almost all of which they were now used, but in small works, in which he had much experience, he thought there were many objections to clay retorts, and considered that brick or iron retorts were far preferable.

The Ewell brick was a capital one for building retorts, and for the arch of the furnace, but not for the walls, as it was a very soft brick. The Dinas brick stood well for the arches and walls of the furnace, but was brittle; the Wortley did not answer so well in the furnace, but were excellent for retorts, owing to the small quantity of carbon deposited on the surface. Irrespective of price, the Stourbridge brick was, in his opinion, the best for general purposes. For a low-priced brick, the Newcastle was the best, and would stand well in moderate heats. In erecting gas works in several parts of Germany he could only obtain fire bricks of a square form, of an inferior quality, and a high price (£12 per 1000), and in most instances he had, notwithstanding the extra carriage and duty, preferred the English brick.

Mr. Douglas stated that he had used clay retorts in small works to great advantage, more especially in Scotland, where cannel coal was used.

Mr. Harris thought clay retorts were not adapted for small works, but considered them very advantageous in large works. He mentioned that the Ewell clay was a very serviceable material for lining gas furnaces.

April 8th.

R. M. CHRISTIE IN THE CHAIR.

ON FIRE-CLAY MANUFACTURES.

(ADJOURNED DISCUSSION.)

Mr. John Cliff was rather disappointed at the absence of all reference to the behaviour of different bricks under different conditions, and thought Mr. Stephenson might have given some information on this point.

Some sanguine manufacturers assert that their goods are not only first class, but that they are the best for any purpose. Some rely on

the fact that because they stand better than others in a gas furnace, they must of necessity do so in a glass or iron furnace; others rely again, on the weathering process, and others follow the Chinese method. Some few makers find, that given the same quality of clay, that clay will make the best brick which is made with as little disintegration of its body as possible (consistent with its liability to fly by sudden changes of temperature), or, in other words, the more clay (of a given quality) you can get into a given sized brick, the longer that brick will resist the wear and tear of fire, gas, or alkali vapour. He thought this assertion would be admitted at once, if the wear of a brick in a furnace was considered. Take, for instance, the crown of a glass furnace, where the fumes from the alkali combine with the brick itself, the glass thus formed on the surface is continuously running down the sides to the floor of the furnace, or falling off in drops; in such an instance, he thought it was clear that the same clay being given, the brick with least weathering of its clay, the heaviest, in fact, of its species, would, because that brick had more clay to be combined with, or formed into glass or slag, take a longer time to waste away than the brick made of same clay on the Chinese or weathering process; and if it takes a longer time for its waste or combination, it is the cheaper brick at a price.

Most persons using fire-bricks are satisfied with asking the price per 1000; and to meet the persevering cry for cheaper bricks, some makers have quietly reduced their sizes—hence the ghosts of fire-bricks that are sent into the market. The price per 1000 (irrespective of any other consideration) is a poor guide, but one almost universally relied on; for instance, here are two bricks, one at 60s., the other at 104s. per 1000 (quality not being considered, although those at 104s. are vastly superior in quality as well), and yet in point of actual cubical contents, the brick at 104s. is less in cost per cube foot than that at 60s.

The author of the paper states, that at the most intense heat, artificially produced, clay refuses to become liquid; he was sorry to differ from him, but he could display a face on Newcastle bricks that have literally fused like treacle, and these the best brands of Newcastle manufacture. The conditions under which they were tried by the

speaker (not once, but until he was obliged to desist from using them) were, they were built to form an annular ring of 3" broad, and 14 ft. high, through which ten fires, of 14" across the arch, and 36" crown to foot, playing for from 25 to 50 hours full fire (and while on this point he might state that the fusing or vitrifying of the Newcastle at such a heat, renders their use in furnaces liable to sudden rushes of cold air, very bad policy), when cooling, the vitrified surfaces chink off from the face and fall down, causing damage to the furnace or its contents. In the case of glass furnaces he believes that the Stourbridge and Laister Dyke bricks, with others, like the Huddersfield bricks, which are made from the Halifax bed of clay, are superior to the Wortley, as the alkaline vapours do not act so readily on them at a high heat as on the Wortley. They have more silica in chemical combination, which is a vastly different thing to silica artificially mixed. He was speaking to a fire-brick maker some time ago, who, as a proof of the quality of his bricks, said it "rung like a bell;" but as any inclination to ringing is an inclination to vitrify, he could not accept that proof. Generally speaking, if a brick contains but alumina and silica it is good, and the addition of iron, lime, or other ingredients, that increase the complexity of the mixture, are more or less fatal as they increase. Silica and lime in some bricks are nearly the whole, and in such a case a little alumina would prove as injurious as lime would in others. He had seen fire-bricks almost black with iron, that stood furnace work very well indeed, but 90 per cent. of the clay was silica; he had seen others with so much alumina in, that, if made from the pure clay alone, they stunted and flew on the slightest alterations of temperature, which is nearly as bad a fault as being fusible. This error was corrected by a large admixture of quartz, sand or gravel, found in close proximity to the works. Under all beds of coal we find either stone or some variety of fire-clay—indeed, that which is clay of easily workable quality at one spot, is often stone at a short distance off. With respect to pugging of the clay at the Wortley Works, the pug-mill has been given up long ago, and the travelling pan (12′ 6" diameter), with 5 ft. rollers, loose on their axles, and supported at their ends on standards outside the pan, has been substituted, as more expeditious, and less expensive to drive. Into this pan the rough lumps from the corves, as filled by the clay-getter in the pit, are

emptied, and at the same time, the proportion of old bricks, sandstone, or other ingredient, is shot in, the water is turned on in measured quantities, and in a much shorter time than by pugging the clay is ready for the moulder. These pans are generally fixed on a first floor, and when the clay is ready, emptied by a large shovel through a hole in the floor into the trucks or barrows underneath. He had seen 15,000 bricks made in a day from one such pan; the clay being to get in the morning. Where it is an absolute necessity to have moulds that wear least on their edges, strips of plate-glass inside a wooden mould answer admirably. In his opinion, if a brick-kiln, instead of being allowed to cool gradually, will not stand the wicket being pulled down when the kiln is "finished off," those bricks are not first rate in quality. That the amount of silica alone is not a safe test of the worth of a clay for fire-bricks. That the blue interior of some bricks is no sign of their being under burnt; it arises from want of air (not that it improves the quality), and that may be supplied either by slower burning, or as in the case of all weathered clays, by leaving a large amount of air-spaces therein. If a brick is put into the kiln too green, and fired too quickly, it is blue, even though the heat raised is more than usual or requisite. Whatever his views were, they had been formed during a close connection for ten years with an establishment turning out over 100,000 fire-bricks weekly, and a large number of gas-retorts, and may, on this ground, possibly claim to be practical.

Mr. Eaton remarked, that a brick from Kinson, in Dorsetshire, possessed the qualities of a good fire-brick, and had successfully stood an extreme heat for 32 hours, in a furnace where wrought iron had melted readily.

Mr. E. Riley said, with respect to weathering clay, it was in many cases absolutely necessary, in order that the small nodules of iron stone that many clays contain might be picked out and separated.

The Chairman in closing the discussion, said, the subject of fire-clay manufactures was one of the greatest importance, and he hoped that, upon some future occasion it would be again brought before the Society. Its manufacture, he considered, was in its infancy, as it was a material which could be used for such innumerable purposes. There could be no doubt it would soon become better known.

April 8th, 1861.

R. M. CHRISTIE IN THE CHAIR.

ON THE SUPERHEATING OF STEAM AND THE VARIOUS APPARATUS EMPLOYED THEREIN.

By PERRY F. NURSEY.

The author, in opening his paper, reviewed the progress of steam engineering from the date of the earliest records. He then proceeded to direct attention to the immediate subject of the paper, observing that the development of the principle had probably been checked by the zeal of some of its advocates, who in attempting to carry superheating to an excessive degree, had met with failures which had the effect of discouraging for a time further pursuit.

Not the less influence, perhaps, had been exercised in this respect by the negative opinions which had been advanced from time to time by its detractors and opponents. Among these was Jacob Perkins, who was so impressed with the inadmissibility of any such condition that, in 1827, he patented apparatus for preventing the possibility of the steam becoming superheated.

The specific advantages offered by superheated steam appeared to be in preventing the presence of water in the cylinders, and insuring that they shall at no time be occupied by anything but pure steam. In condensing engines the interior of the cylinder being open to the condenser during half the time of each revolution of the crank was, therefore, during that period, exposed to the influence of the low temperature of the condenser. There then ensued a consequent rapid radiation of heat, from the sides and ends of the cylinder cooling down the whole mass of metal. The steam admitted at the next stroke, coming in contact with these cooled surfaces, heated them up again, losing thereby a portion of its heat, and the consequence was the deposit of a quantity of water in the cylinder, from condensation of an amount of steam proportionate to the quantity of heat imparted to

the metal of the cylinder. If the expansion was carried down to a sufficiently low pressure a portion of the water might be evaporated again into steam towards the end of the stroke, but its effective value would have been lost during the previous portion of the stroke; in other words, condensation took place at the beginning of the stroke, and a partial re-evaporation at the end, on account of the metal of the cylinder being colder than the fresh high pressure steam entering from the boiler, but hotter than the expanded steam in the cylinder at the end of the stroke. Therefore, if as much heat were added to the steam, by superheating it before entering the cylinder, as would supply the amount of which it was deprived by the cylinder, it would remain perfectly dry steam throughout the stroke, and no water would be deposited.

This appeared to be the mode in which the superheating of steam acted in producing a saving of steam and consequent economy of fuel, by preventing the extensive waste of steam that ordinarily took place, and this indicated the extent to which superheating could be carried with any great advantage.

The opinion of Mr. John Penn was, that an addition of 100 deg. of heat to the temperature of the steam insured the accomplishment of the desired object. With steam at 20 lb. per square inch above the atmosphere, as used in marine engines, it was thus heated from a temperature of 260 deg. to that of 360 deg., and was then only about as hot as the ordinary high pressure steam of 120 lb. per inch used in locomotive engines.

Therefore, to superheat the steam before it entered the cylinder was a simple and eligible mode of attaining the desired object, and appeared also preferable to a steam jacket, because to carry out the object fully would require the steam in the jacket to be superheated, and even then the heat was applied outside the cylinder, and had to pass through the thick metal, but, by the introduction of superheated steam into the cylinder, the object was accomplished in the most direct manner—the surface of contact being heated.

According to Mr. E. A. Cowper, the effect of superheating upon steam was, in the first place, the evaporation of all the moisture in it, thereby depriving it of the minute particles of water that invariably

were found to accompany it from the boilers, even where there was no sensible priming. It would then become perfect or dry steam, but at first would not be raised in temperature; but if the superheating was carried beyond that point the temperature of the steam would be raised by all the heat added, and its volume proportionately increased, causing an increase in the total quantity of steam supplied at the same pressure, and from the same evaporation of water.

As a rule steam was expanded by increase of temperature, at the same rate as air and other gases. Therefore, since air at 32 deg. was doubled in volume by an increase of temperature of 480 deg., steam at 20 lb. per inch, or 260 deg., would be double in volume by 708 deg. increase of temperature ($480 + 260 - 32 = 708$), and a rise of 100 deg. from 260 deg. to 360 deg. would, consequently, increase its volume one-seventh, causing an equal saving in consumption of fuel, when the superheating was effected by using the waste heat of the smoke box.

From actual experiments, however, made by Mr. Fairbairn, it appeared that when ordinary saturated steam was superheated its expansion for the first 5 deg. was three times as great as that of air, but as the superheating was increased the rate of expansion gradually fell off to that of air.

The mode of superheating steam was susceptible of variation. The general principles to be regarded were the construction of the apparatus of such a form as should present the necessary extent of heating surface within a limited space. The placing it where it should neither form an obstruction nor be exposed to a heat that might cause injury, and the making use of the heat when the boiler had done with it, so as to require no extra fuel in attaining the object.

The question appeared to have received definite attention about twenty-eight years since from Mr. Thomas Howard, who used a dry boiler, injecting at each stroke of the engine only enough water to produce the requisite amount of steam. Mr. Howard's experiments fully established the economy effected by the principle, but the apparatus was of too delicate a nature for general practical adoption, and was consequently relinquished. The subject was subsequently advocated by Dr. Haycraft, whose strong opinion was that the prin-

ciple would ultimately become generally adopted, and would be found to affect a saving of 30 per cent. in fuel. The results of practice coincide in a remarkable manner with this opinion.

Mr. Penn made trials on a large scale, and arrived at the conclusion that a saving of from 20 per cent. to 30 per cent. in fuel was to be effected; that a moderate extent of superheating enabled all the important advantages of the plan to be obtained; and that nothing objectionable was necessarily involved from extra wear and tear, risk of failure, complication of apparatus, or difficulty in lubrication.

The arrangement employed by Mr. Penn, in a trial of the plan in the Peninsular and Oriental Company's steamship Valetta, of 260 nominal horse power, consisted of two horizontal faggots of tubes arranged in vertical rows, with clear spaces between them horizontally for access to clean the boiler. These tubes were fixed into three flat chambers, and placed in the smoke box (Fig. No. 1). The steam was supplied from the boiler to the centre chamber, and passing through the superheating pipes was taken off from the end chambers by the steam pipes to the engines. The steam pipes had also direct communication with the boilers, so that the superheating apparatus could be disconnected.

Two trips were made by the vessel from Malta to Alexandria and back, with the superheating apparatus; and then two similar trips with plain steam. The result was a saving of 20 per cent. of fuel in favour of the apparatus.

In 1856, Mr. John Longbottom patented apparatus for surcharging or superheating steam. This he proposed to effect by bringing the steam from the boiler directly in contact with the outer surfaces of a series of tubes heated by the ordinary boiler furnace, or by a separate one, if necessary. The tubes might be partially filled with water, and so disposed as to produce a rapid circulation of water and heat through them. A number of tubes in a casing might be placed in or near to the condenser or otherwise so as to be in close proximity to the cylinders, by which means the steam, when used expansively, would become superheated, and therefore give off a greater amount of motive force.

The next exemplification was that of Mr. David Patridge, assistant

chief engineer of Her Majesty's Dockyard, Woolwich, who, early in 1857, patented apparatus for superheating steam. The diagram No. 2 represented Patridge's apparatus as fitted in the Brazilian mail packet Apa, 250-horse power, and perfectly illustrated his principle. The apparatus was extremely simple, consisting of an iron cylinder, placed vertically in the uptake fitted with tubes of from 3 in. to 4 in. diameter, and running parallel with its length, through which the products of combustion passed. The steam from the boilers entered the cylinder from two opposite points, circulated around the heated tubes, and passed through an outlet into the steam pipe to the engines. Upon the outlet pipe a small safety valve was fitted, opening into the uptake.

In general the steam was superheated to about 340 deg. at the boilers, the pressures ranging from 10 lb. to 25 lb. per square inch in different vessels. The savings varied from 15 per cent. to 30 per cent.

To Mr. Patridge was due the credit of having fitted with his apparatus the first vessel that ever left England, working with superheated steam unmixed. This was the Prince Alfred, of 200-horse power, belonging to the Intercolonial Royal Mail Company. The superheaters were fitted more than four years since, the immediate results being of a highly successful character, and they continued so to the present time, a saving of more than 30 per cent. being effected. The apparatus had never once been out of order or under repair.

In a report from Mr. Lowes, the chief engineer of the Prince Alfred, he stated—" We find a great benefit with the superheating apparatus, saving from 30 per cent. to 35 per cent."

The author had a list of fifty-two vessels fitted with Patridge's apparatus, representing a total of 10,673 horse power. The list included one set of boilers of the Great Eastern, 533-horse power in addition to those were many others fitted, and being fitted, in all parts of the kingdom.

Johnson's arrangement consisted of pipes placed in the flue of the furnace, and communicating at one end with a valve chest in connection with the boiler, and, at the other, with a valve chest in connection with the steam-pipe to the cylinders. The valves consisted of slides working over two mouths of two sets of superheating pipes,

so that each set might be brought into action alternately, the valves working in concert for that purpose. Provision was made for returning the steam to the boilers after leaving the cylinders, the pressure being low.

The object here appeared to be to attain the utmost degree of economy; but whether this would be the result in practice was doubtful, inasmuch as the presence of machinery, of a comparatively complex character, implied increased first cost, and a liability to derangement. Where simplicity in construction and directness of communication were departed from in superheaters, the object was so far lost sight of as to render success very problematical.

The author next proceeded to describe Messrs. Parson and Pilgrim's apparatus, and to notice the effect superheating had upon steam in a chemical point of view, mainly with reference to the question of liability to explosion attending its employment at high temperatures.

The apparatus consisted mainly of three arched pipes placed in each boiler-furnace (see Fig. No. 3). A pipe from the steam chest conducted the wet steam under the fire-bars to the superheating apparatus, which it traversed, and, returned by another pipe under the furnace-bars to the engine.

In their investigation of the subject the patentees had a 10-horse power boiler fitted with their apparatus. The results of nine months' experiments, both with plain and with superheated steam, were that with the latter they consumed one-third less water and one-third less fuel. They also found that, in some cases, one arched pipe would be sufficient to realise the benefit of their invention.

At the close of 1858 they applied their apparatus to one of the boilers in the gasworks of Woolwich Arsenal, using three pipes, with a result which might be gathered from an extract from a report made to the War Office, by Mr. Anderson, inspector of machinery in the Royal Arsenal.

Mr. Anderson had stated that during the experiments which in each case lasted 32 days, upwards of 700,000 revolutions of the engine were made, both by superheated steam and with common steam. That to perform one revolution the superheated steam required ·7459 of an ounce of coke, or barely three-quarters of an ounce, while common

steam required 1·0673, or a little more than an ounce, or, to put it in another form—

		Ounces.
"93·7 revolutions, with common steam, required	... ...	100
"93·7 ,, ,, superheated steam, required only		69·88
		30·12

"Showing a saving of fully 30 per cent. in fuel."

The question of danger of explosion having been raised in respect of this apparatus, the patentees had consulted Dr. Taylor and Mr. Brande on the point.

The author proceeded to read the elaborate reports of those gentlemen, and likewise another upon the subject from Professor Faraday, who had been consulted by the Board of Trade.

From those reports it appeared there was no danger of explosion whatever.

The system had also been applied to her Majesty's steam tug Bustler and to fifteen vessels in the mercantile marine. In the Bustler the apparatus had burnt out so fast, and the vessel had been so often laid up for repairs, that it was ordered to be removed, and was subsequently substituted by one pipe at the back of the boiler (as shown in the dotted part of the diagram), which was now on probation. From this arrangement results were obtained equal with those from the three small pipes. It, therefore, appeared preferable.

The cost of the apparatus was £2 per horse power.

The only part liable to injury from the heat of the fire appeared to be the arched pipes. Those the patentees proposed to protect by fire-bricks made for the purpose. That they, however, did become unfit for duty in the course of a comparatively limited time was apparent, not only upon consideration, but from the circumstance that the patentees stated the additional expense, after the first cost of £2 per horse power for the apparatus, was the keeping in store of about a dozen of the arched pipes, at a cost of from £20 to £30, and this where the single arched pipe was employed.

Improvements with respect to increasing the area of the heating

surface of superheating pipes were patented by John Greenwood in 1858. He also proposed to form the plates of boilers with indentations, so as to double the heating surfaces.

The author questioned the practical efficiency of those plans, on the scores of expense in production, increased fouling, and difficulty in cleaning.

Mr. Oram had worked that system out in a manner sufficiently dissimilar to create the subject of another patent. He proposed tubes of spiral, corrugated, undulated, or indented forms.

The author noticed those inventions because they each claimed a specific adaptation to superheating steam, and he thought every principle, however collateral or auxiliary only to the main object, was worthy of consideration, for each might be found susceptible of modifications, which, in combination with other systems, might lead to favourable results, however distant they in themselves, without investigation, appeared.

Mr. Lamb, of the Peninsular and Oriental Company's service, was at one time an objector to superheating steam, but, near the close of 1858, he had patented apparatus of a very efficient character, Figs. 6 and 7, in which he endeavoured to dry the steam as perfectly as possible, by dividing it into thin sheets or streams, of from ½ in. to ¾ in. in thickness, in transit from the boilers to the cylinders. The method he adopted in practice, was to use a chest made with 5-16ths in. iron plates, and divided vertically by ½ in. malleable iron plates, so as to allow the heated products of combustion to pass through one set of spaces, while the others were enclosed in the chest through which the steam passed.

The arrangement admitted of common steam being used. This plan was occasionally adopted as a precautionary measure, but was not necessary.

The best results had been obtained with steam at from 300 deg. to 312 deg., and several ships were working with the apparatus, very economically, at from 280 deg. to 300 deg.

Lamb's superheater had been applied to upwards of fifty steam vessels. The amount of saving effected was found to vary from 20 per cent. to 40 per cent., according to circumstances; a fair average

working economy of at least 25 per cent. in coals alone, with equal speeds, could always be secured. The usual pressure at which the apparatus was worked was from 20 lb. to 25 lb. They were, however, always proved to 60 lb., and could be stayed to any strength; the more stays introduced the greater their efficiency, since the stays aided in imparting heat to the steam.

The apparatus had the advantage of compactness; it could be adapted to any boiler; it appeared to secure the full beneficial effects of thoroughly superheated steam, and it did not make the steam too hot. It would possibly outlast the tubular system, but its construction involved heavy prime cost; but, high as this comparatively was, the apparatus had, in several instances, paid for itself in three or four months, and, at the most, it did so in six months.

Messrs. Boden and Clark, of Southampton, used a superheater, which consisted of a rectangular iron chest fitted with tubes, open at their ends, through which the heated vapours passed.

This apparatus was fitted on board the Southampton, running between Southampton and the Channel Islands, and in which vessel the author made a trip to and from Jersey, a short time since, which afforded him an opportunity of inquiring into the working of the superheaters.

The Southampton was fitted with 262-horse power condensing engines with two slide oscillating 60 in. cylinders, 5 ft. stroke; had two boilers, and worked at 15 lb. pressure, regulated by a Government lock-up valve, as she carried the mails. She burnt 37 tons of coal on the trip out and in, averaging 22 hours. This quantity was inclusive of 6 tons used in getting up steam in harbour, which brought it to 31 tons, or about 12 lb. per horse power per hour, a much less quantity than that consumed by either the Courier or Dispatch, boats of only 200-horse power each, on the same station, working with saturated steam. The temperature of the steam in the steam pipe was 305 deg., and on the slide jacket 275 deg. The heating surface in the superheater was less than intended, being only 1¾ square feet per horse power; it ought to have been 2½ square feet. The tubes in the superheater were the same as in the boiler. The cost of the apparatus was £2 per horse power. Since October, 1860, and up to the 17th

February last, the Southampton had made 33 voyages, and run a total of 10,000 miles. There had been no trouble with the apparatus, and the packing was in no way injured.

The feed water apparatus was not necessarily an appendage to the superheater, and could be fitted or not, as desired, There would doubtless, be a further saving effected by supplying the water to the boiler at a high temperature rather than at a low one.

The author observed that steam with a pressure of 15 lb. on the square inch required to be kept at an uniform temperature of 250 deg. to maintain that pressure. To increase the temperature in the boilers would there be useless, as no corresponding increase of power would be obtained on account of 15 lb. being there the imposed maximum limit. Therefore, as the steam in the boiler could not range beyond 252 deg., and it was found at 305 deg. in the steam pipe, it was clear the capacity of the superheater, with its limited area, was to impart to it an additional 53 deg. of heat to the advantages of working. Thus, while observing the Government regulation in the boiler, the engines were worked by steam at a temperature equal to a higher pressure.

In a recent trial trip of the Dispatch, which had just been fitted with Boden's apparatus, the speed of her engines was 36 strokes per minute; pressure of steam on the boiler 15 lb. per square inch; temperature on steam pipes, from the superheater, 344 deg.; ditto on slide valve, 333 deg.; heating surface in the superheater, 2¼ square feet per horse power.

The amount of superheating surface was greater than in the Southampton, by ¾ square feet per horse power, and the advantage was manifest by the increase of 39 degrees of temperature in the steam pipe above that in that vessel.

Mr. William Wain, of the Royal Dockyard, Copenhagen, patented an arrangement for superheating, which applied chiefly to boilers of cylindrical form with tubular fire-places. Above the fire-places a series of tubes were arranged, through which the products of combustion passed into the smoke-box and uptake, passing on their way through a horizontal flue or passage placed between two boilers, the smoke-boxes and uptake being connected with this flue at each end. The superheater consisted of a large iron steam pipe of suitable strength, sup-

ported within and surrounded by this flue between the boilers. The superheater received the steam from the boiler; it passed along the superheater to the other end nearest the engine, to which it was conducted through the ordinary supply pipe. The superheater was furnished with intersecting tubes, placed at different angles, which gave an increase of heating surface. The author believed that Mr. Wain had applied his apparatus to several boilers, but he was unable to supply any actual results.

Butlin's superheater (Fig. 10) consisted essentially of a chamber which was fixed within the smoke-box parallel with the tube-plate, and was provided with short tubes, placed in exact continuation of the boiler-tubes. The upper part of the chamber at one end communicated through a pipe with the steam chest, and the other end opened into another pipe, which conveyed the superheated steam to the cylinder of the engine. A tube, fitted with a valve opening into the steam chest, was mounted upon the outlet pipe, and served the purpose of admitting saturated steam if desired.

To prevent injury to the superheaters, while the steam was being first raised, the chamber was filled, on or before commencing to fire up, with water from the boiler; when steam was produced the water was drawn off. The apparatus might be adapted to heat the feed water only.

This apparatus had been applied to the boilers both of marine and portable engines. The author referred to one which had been fixed some time on board the City of Nantes steamer. A letter from the owners of this vessel stated that the apparatus effected a saving of at least 30 per cent. in the consumption of fuel, besides giving additional speed upon the screw.

The cost of application was about 35s. per horse power. Beyond the trials noticed the author was not aware that the apparatus had been applied; but from those a *prima facie* case appeared to be made out in its favour. It could be fitted at a less cost per horse power than most others, and realised parallel results with the more costly ones. But against that the drawback was the necessity of charging the chamber with water whilst firing up, which objection was absent in most others.

Messrs. Pullan, Cresswell, and Longstaff's apparatus, for which they obtained a patent in May, 1860, consisted of an arrangement of steam-pipes connected with the boiler, and passing through the tubes of the boiler to the cylinder. It was applicable to high-pressure, marine, locomotive, and stationary boilers.

The author inspected the apparatus, at Mr. Cresswell's works, as adapted to a portable engine in which, formerly, great difficulty was experienced in keeping up the steam for more than an hour at a time. They could now keep steam with the fire-doors open. The engine referred to worked at 35 lb. pressure, or 283 deg. The temperatures were indicated by Negretti and Zambra's gauges. Before the super-heating had reached 100 deg. the author tried the cylinders, and found no priming whatever was taking place. The apparatus appeared to act very efficiently. It was found to effect a saving of one-third man's time, one-sixth of feed-water, and over 30 per cent. in fuel and more power was got out of the engine.

Cresswell's superheater was also applied to a traction-engine, where it was found invaluable. In the first place the difference in the quantity of water required enabled them to travel seven miles in lieu of five without filling up the tank, thus effecting a saving in time. Secondly, instead of having a large volume of steam issuing from the funnel, which was highly objectionable on common roads, it was scarcely to be noticed that the engines were at work. Reckoning the increase of the power of the engines—as the steam enters the cylinders at 300 deg. instead of 220 deg.—the average saving in fuel was computed at from 35 to 40 per cent. The cost of the apparatus was £2 per horse power for large boilers; for those of a smaller description the price was somewhat higher.

Near the close of 1860 Mr. Newton proposed to prevent oxidation in superheating pipes by passing steam from the boiler to a retort containing black protoxide of iron, or other metals, and iron turnings; the retort being placed in the furnace or flues, or in a separate furnace.

The necessity of this arrangement appeared to be negatived upon a consideration of the reports of Professor Faraday and others already noticed, the deduction being that the chemical action it was here

proposed to prevent existed only to a very limited and unobjectionable extent.

The author proceeded to notice Beardmore and Galloway's boiler and apparatus for superheating steam, represented in diagram No. 11. The boiler shown was of 100 nominal horse power, and contained 174 tubes 5 ft. long and 3 in. outside diameter. It had three fire-places, each 3 ft. 4 in. wide by 3 ft. 8 in. high, the fire bars were 7 ft. long, diameter of funnel 3 ft. 6 in.

The superheating apparatus consisted of two chambers communicating by means of 102 tubes 5 ft. 6 in. long and 3 in. outside diameter, arranged in two sets or faggots. The steam from the boiler entered at the top of the right hand superheating chamber, which was divided half way down, so that the steam was thereby directed along the upper set of tubes to the left hand chamber, returning along the lower set of tubes to the lower half of the right hand chamber from whence it was conducted by the steam pipe to the engines.

The temperature of the steam was from 350 deg. to 360 deg., and in was used unmixed. The amount of saving in fuel effected was 25 per cent. The superheaters had been applied to numerous large steam vessels and had been at work in some of them for upwards of two years, having answered in a very satisfactory manner.

Wethered's apparatus for using combined steam, was described as consisting of two pipes leading from the steam chest of the boiler to a chamber or reservoir placed intermediately between the boiler and the engines. One of the two pipes passed direct to the chamber conducting thereto ordinary or plain steam. The other pipe on its way to the chamber was made to pass through the furnace, the steam conveyed by it, therefore, was highly dried or surcharged. The contents of each pipe became mixed in the intermediate chamber, thus the steam was supplied to the cylinders at an increased temperature upon that of the boiler steam, such increase being determined by the relative volumes of wet and dry steam. With a 12-horse power engine it had been ound that with a steam pipe 2⅝ in. diameter by 9 ft. 6 in. long, and a surcharging pipe 1½ in. diameter by 15 ft. long, all the advantages resulting from the use of saturated and superheated steam in combination were obtained.

In connection with the subject the author introduced Ramsden's patent boiler as being one likely to effect a great saving in fuel, and at the same time to superheat the steam to a considerable extent.

This boiler, or group of boilers (see drawing No. 12), was formed by constructing chambers having one side flat and the other sides and ends semicircular. These chambers were placed upright and connected together in pairs, with their flat faces opposite, by horizontal water tubes. They had also communication with each other at the bottom by pipes, thus a free circulation of water throughout the group was kept up. The chambers were connected at the top by cylindrical steam chambers, which were exposed to the influence of the heated vapours from the furnace. The steam was transmitted thence to the engines along steam pipes carried through the uptake, by which it became further dried or superheated.

One of these boilers had been constructed by Messrs. Horton and Son, of Liverpool, and was at Glasgow, and nearly completed fitting on board the Auralia, a new screw steamer of 1,800 tons, fitted with engines having four cylinders of 43 in. diameter, and 2 ft. 6 in. stroke. All the cylinders were to be worked with steam at 100 lb. pressure. There were two pieces of boiler which had been tested to 210 lb. water pressure. Each piece was composed of five pairs of chambers. having thirty-five tubes, being in the total for two boilers 350 tubes of 6 in. external diameter by 6 ft. 3 in. long, and having an area of 144 ft. of grate surface. The boiler was enclosed in a casing, and it was not intended to apply any special superheating apparatus until the effect of exposing the whole upper part of the boiler to heat had been ascertained.

The author observed that this proposition was about the most recent in regard to the subject. Having, therefore, followed the matter up, as near as was possible, to the present period, he here drew the practical investigation to a close.

The author was obliged to omit noticing several inventions from not having been able to obtain such information respecting them as he would be justified in laying before the meeting. He had illustrated principally those which, either from their general use or their own apparent merits, might be considered the best examples of the

system. Those of questionable utility he had introduced for the purpose of comparison with those whose efficiency had been established and also that the question might be as fully considered as was possible in a paper.

Having pointed out advantages and defects as he proceeded, the author proposed to submit the conclusions he had arrived at with regard to the best method—out of many good ones—for carrying out the principle of superheating steam, and of thereby obtaining the advantages already detailed.

Upon the principle itself opinions could scarcely differ when practice had determined its high efficiency. Bearing in mind the principles laid down in the early part of the paper, upon which depended the successful practical exposition of the system, the author did not think he should have many dissentients when he expressed his conviction that the apparatus which appeared perfectly to fulfil the imposed conditions, as applied chiefly to marine boilers, was that of Mr Patridge. He could not make an exception in favour of Boden and Clark's, because for it they appeared to have no patent, and because it was virtually Patridge's arrangement, which also appeared to cover Butlin's method.

Lamb's apparatus implied greater efficiency, as it offered a greater heating surface; but it was more expensive than Patridge's, than which it really could not be more efficient; if Patridge's effected all that was required its extra capacity became superfluity.

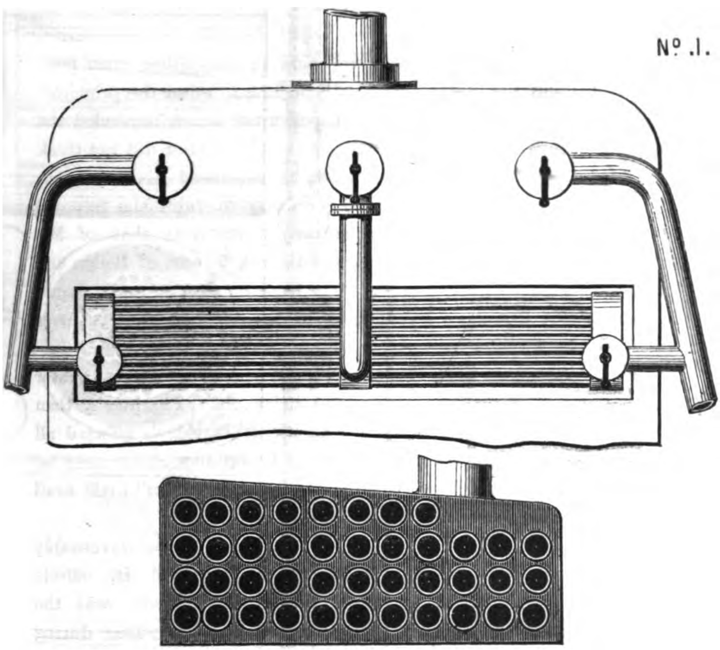
The simplicity of Parson and Pilgrim's plan was of little avail against its extra cost and want of durability.

For boilers of a smaller description the author was favourably impressed with Cresswell's method, having observed its effects in use, it was more simple than Butlin's, and there was the absence of necessity of protection by charging with water during the firing up.

All other conditions being perfect, it ever required time—the grand solvent of all problems—to determine the adequacy of any proposition claiming to fulfil a specific object. To this test, perhaps, Cresswell's apparatus had yet to be submitted, with, however, every prospect of success; although, in practical development, obstacles and imper-

fections, such as no foresight could guard against or precaution obviate, would sometimes be found to present themselves.

To surmount such contingencies was to be the successful expositor of progress.



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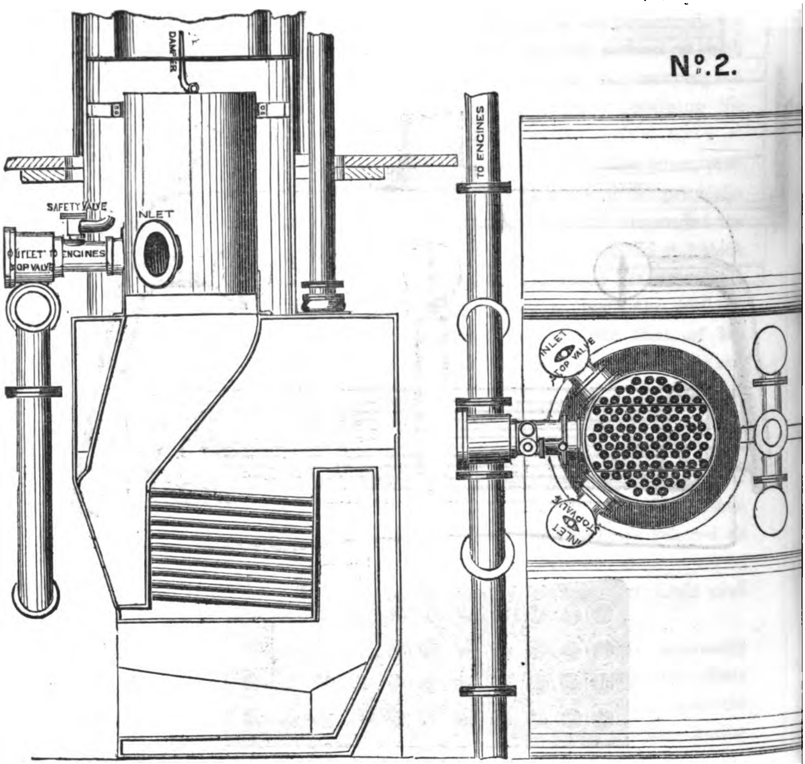
E 2


DAMPER
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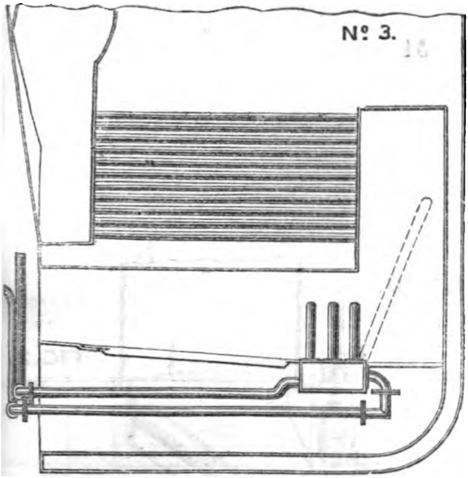

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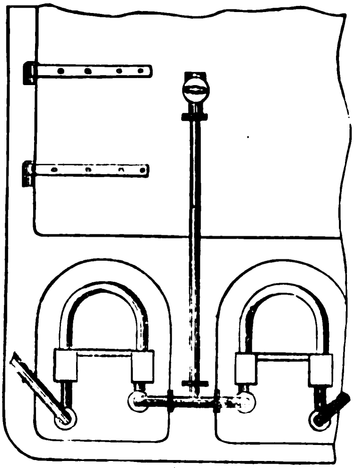

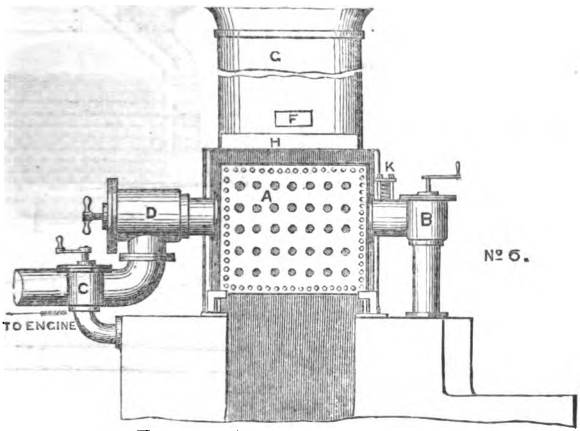

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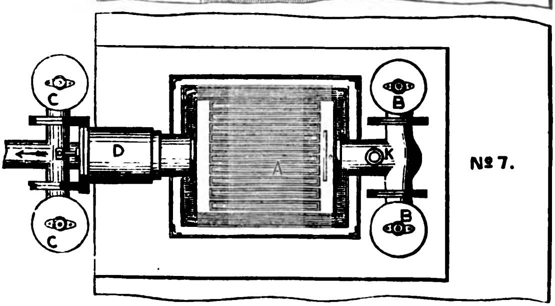

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Nº. 10.

FIG. 1.

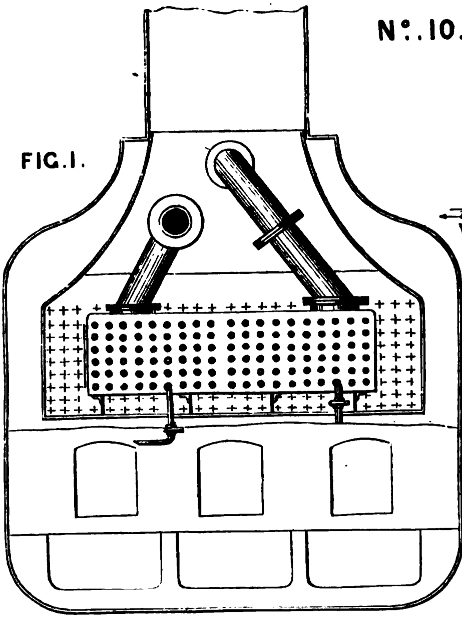
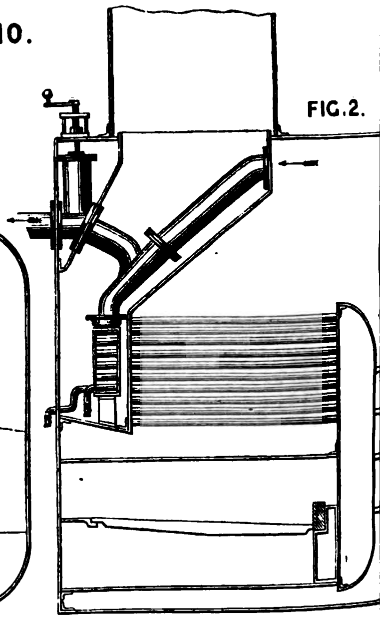


FIG. 2.



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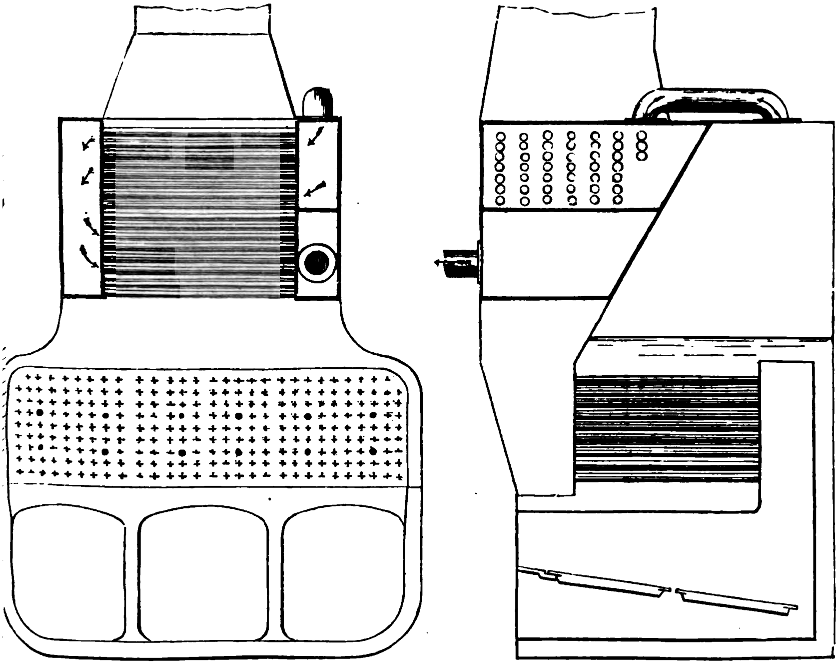

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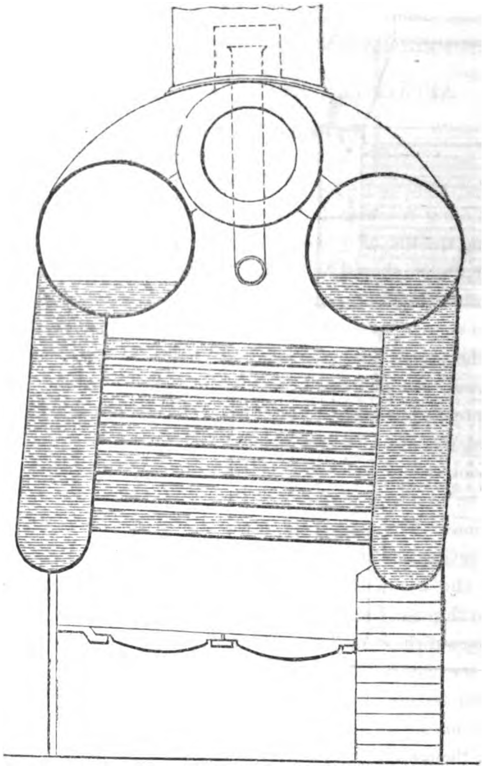


May 6th, 1861.

J. AMOS IN THE CHAIR.

ON THE SUPERHEATING OF STEAM AND THE VARIOUS APPARATUS EMPLOYED THEREIN.

By PERRY F. NURSEY.

DISCUSSION.

Mr. F. Young considered a superheating apparatus as only a means of prolonging the life of a system of ill-designed boilers at present in use: a good boiler should superheat and utilize all the heat evolved from the fuel without requiring the addition of any apparatus. Most boilers were very badly designed, they had small steam room, and consequently the steam was charged with moisture, there was a great waste of heat, and the steam was scarcely ever maintained at the originally intended pressure; and from entering the cylinders at that low pressure, was more easily robbed of the force it should develope.

The patent cylindrical spiral boiler of Randolph, Elder and Co., he considered to be nearly perfect, and the best boiler yet designed for marine engines. The waste heat in the funnel after it had left contact with any heating surface did not exceed 480 deg., and it gave great economy in the use of the coal, and an absence of smoke. The boiler of the screw ship San Carlos, of 120-horse power, at a pressure of 50 lbs. on the square inch, indicated 531-horse power, burning 1,120 lbs. of coal = 2·1 lbs. coal per horse power per hour.

These boilers use the ordinary sea water, and after steaming more than 30 000 miles, are perfectly free from any derangement, and the ships using them have never been more than three days in any port at a time. Every part of the boiler is easily accessible to a man, no stays are required, there being no flat surfaces, and the pressure is every where internal. The cost is very little more than that of the ordinary marine boiler.

Mr. Pilgrim stated that he had worked steam at from 380 deg. to 400 deg. for 14 months, and the cylinders, piston, and the faces of the workings of the engine, were not at all injured, nor did he find the packing effected in any way.

Mr. Glynn observed that with regard to superheating generally during the last few years a great deal of discussion had taken place, and as everybody endeavoured to obtain as much power as possible, superheating became imperative with the present badly constructed boilers With reference to wet steam, the evil might be remedied by the insertion in the steam-chest of a number of iron balls, which effectually prevented the passing of wet steam to the cylinders.

Mr. Carrington in 1847 had made some experiments upon isolated steam to ascertain its expansion; he found that it did not expand in a straight line, for at the beginning of the line, it began to rise very rapidly, and afterwards ran parallel with the expansion of air; he therefore concluded that the expansion of all gases was equal and parallel at the same distance from the generator. He believed that with some good oils or fatty matter which would not boil at less than 600 deg., steam could be superheated to 450 deg. or 500 deg. with safety. In Benson's steam boiler, by means of horizontal tubes, superheating could be carried on to any degree, and by adding to, or taking from the layer of tubes, the temperature could be adjusted to any degree that might be required.

Mr. Young, referring to the apparent absence of sensible heat from steam at high temperatures, observed that he had held his face four inches from the upper gauge-cock of a boiler, with steam at 360 lbs. pressure, and could not detect the slightest sensibility of heat.

Mr. Riley said it was a well-known fact that cold was produced by the expansion of compressed gases, the sensible heat becoming latent. Some time since in Wales, a winding engine was erected underground, which was worked by compressed air from the surface, and it was found that ice was formed at the escape pipe from the cylinders.

Mr. Morris stated that in Mr. Penn's factory steam was superheated by means of an apparatus entirely separate from the boiler, by which a saving of about one-third in fuel was effected.

The Chairman said his experience was entirely confined to the appli-

cation of the superheating principle on land. He had found that practically where well-proportioned boilers were in use, with abundance of steam room, and heating surface, the gain was not material where superheaters were employed.

They applied excellently to cases where long lines of exposed steam piping existed; as they obviated to a certain extent the excessive condensation of the steam, and he had found the gain in one case to amount to nearly 15 to 20 per cent. in fuel.

The same observations applied to cases of insufficient boiler room, otherwise where the temperature in the uptake did not much exceed 300 degrees, but little was to be gained by superheating, and as much or more might be done by a judicious system of heating the feed water.

On board a ship everything which saved fuel, gave more space for cargo, and if the application of superheaters did away with the priming which was one of the greatest drawbacks incidental to marine boilers, it was clearly a very great improvement. As a matter of prudence he considered that every boiler should be arranged so as to work either with or without the superheaters.

May 6th, 1861.

J. AMOS IN THE CHAIR.

ON THE MANUFACTURE OF IRON.

By EDWARD RILEY, F.C.S., late of Dowlais Ironworks.

The author commenced by stating the importance of the manufacture of iron, and attributed to the use and application of iron, in various forms, the pre-eminence that England claims for her vast and stupendous works and manufactures.

The extent of the subject he brought before them necessarily precluded him from giving more than a general outline of the various processes in the manufacture; his object was to endeavour, as far as he was able, to account for some of the various qualities of iron.

After admitting that practice had far outrun theory, and it was only recently that inquiring minds had began to investigate the various causes that affect the quality of iron, he proceeded to consider the different ores used in this country.

Commencing first with the clay ironstones of the coal measures, which had, until recently, been the ore almost exclusively used for the manufacture of iron, the author then mentioned the discovery of the Black Band, which was a carbonate of iron, and somewhat similar to the clay ironstone, only containing more coaly matter, and generally more sulphur, as iron pyrites. This ore was very largely used in Scotland, and partly in Wales; it is found in thick beds or layers, 3 ft. to 4 ft. thick, whereas the clay ironstone only occurs in thin layers, a few inches in thickness, in the mine shale, and is necessarily much more expensive than the Black Band. These ores are nearly always calcined.

Before the introduction of railways scarcely any other ores than the above were used, as they are always found associated with the coal. Although much richer ores were known, such as the red hematite, from the difficulty of conveyance they were only used to a limited extent. On the introduction of the railway system the rich ores were largely imported, and not only increased the production, but diminished the cost of iron, enormous quantities of the red hematite being imported into Wales and Staffordshire, from Lancashire and Cumberland, where the ore occurs massive, from 15 ft. to 30 ft. thick. The yield of this ore in the furnace is from 50 to 55 per cent., whilst the clay ironstone does not yield, on an average, more than 25 to 30 per cent. The author referred to the following Table, containing the analyses of the various description of ore.

The next ores considered differed from the above only in being a hydrated peroxide of iron, or brown hematite. As a rule, these ores were more siliceous than the former, and the yield of iron was from 38 to 45 per cent. They were imported largely from the Forest of Dean, Cornwall, and Devonshire, where they occur several feet in thickness. They are also found in some localities in South Wales, at Llantrissant, Pentyrch, and Wenvoe.

The oolitic ores were then described, the principal deposit being that of Cleveland, where, within a few years, an immense iron district

TABLE I.—*Analyses made by the Author.*

	Carbonates of Iron.								Oolitic Ores.					
	Clay Iron Ores.			Blackband	Cleveland Ore, also Oolitic.		Spathose Ore.		Northampton Ore.		Wiltshire Ore.		Lincolnshire Ore.	Clay Ore Calcined
Silica (soluble)	·27	·08	·14	—	† 7·12	† 9·46	—	—*	*Peroxide	—	—	Protoxide of Iron 5·31	Soluble Silica ·19	—
Protoxide of Iron	41·03	38·77	44·29	48·66	39·92	39·00	43·55	44·37	**55·13	73·70	64·61	47·98	40·19	76·61
Alumina	·23	·32	·45	Clay 1·21	7·86	7·46	—	—	2·11	·87	3·85	6·48	2·17	5·79
Protoxide of Manganese	·55	1·30	1·13	1·21	·95	1·30	13·46	8·94	** ·53	·74	·64	·44	3·66	1·21
Lime	2·83	4·45	3·06	1·69	7·44	7·44	·19	·27	·99	1·13	—	5·02	18·98	3·13
Magnesia	3·11	4·25	3·73	2·61	3·82	3·82	3·87	10·04	·38	·17	·20	1·32	·67	3·96
Carbonic Acid...	28·49	30·53	32·48	33·09	22·85	23·06	39·04	40·01	·40	·16	—	4·93	13·34	—
Moisture	·57	·35	·42	·25	—	—	·06	—	7·19	4·89	1·64	—	3·09	—
Combined Water	1·36	1·08	1·03	—	2·97	3·66	—	—	9·57	11·20	10·21	7·15	7·00	—
Phosphoric Acid	·70	·46	·42	·58	1·86	1·60	—	—	1·27	1·31	·64	1·88	1·80	·57
Organic Matter	·07	·29	·35	11·08	*·03	—	—	—	—	—	—	·60	—	—
Insoluble in Acids (Clay). Silica	13·08	13·47	7·77	—	1·50	—	·36	·93	Clay & Sand 22·67 { 18·80	Clay & Sand 8·47 { 5·47	18·02	16·47	Clay & Sand 8·91 { 7·37	8·38
Alumina	5·56	2·96	3·75	Iron ·03 Sul. ·04	·10	—	—	—	3·23	1·00	—	1·27	1·28	—
Per-oxide of Iron	·41	·40	·41	—	3·60	3·50	—	—	·37	·25	—	·24	—	—
Lime	·17	·09	·12	—	Iron ·05	—	—	—	—	—	—	Iron ·21	Lime ·08	—
Magnesia	·25	·15	·19	—	Sul. ·06	—	—	—	—	—	—	Sul. ·24	Sul. Acid ·12	Sulphur ·06
Potash	·86	·87	·74	—	·27	—	—	—	—	—	—	·28	—	·87
	99·54	99·82	100·48	100·45	100·40	100·30	100·53	99·56	100·24	100·64	99·81	99·82	100·20	100·58
Metallic Iron	32·18	30·43	34·72	37·80	33·62	32·78	33·87	34·51	38·60	53·34	45·22	38·08	28·10	51·62

* Titanic Acid ·03.
** Peroxide refers to the following columns.
† Analyses extracted from analyses made at Woolwich Arsenal.
† Also Oolitic.

has sprung up. This ore occurs in an immense bed of 18 ft. in thickness, of which 15 ft. are worked, the rest being left for roof. It is got partly by open and partly by subterraneous workings. The cost of the ore is very small in many works, not being more than 2s. 6d. per ton on the top of the furnace, whilst the clay iron ores of South Wales and Staffordshire cost as much as from 12s. to 14s. per ton, and they are not so rich as the Cleveland ores. The cost of the hematites depends on the locality (where used); in Wales, red hematite is about 20s. per ton, and brown 14s. to 15s., depending on its quality. The Cleveland ore is a mixture of a green carbonate of iron, with a little silicate of iron. It is always calcined before it is used in the blast furnace. The other oolitic ores are the Northamptonshire and Wiltshire ores. Some are found in Lincolnshire and a little in Oxfordshire. These ores are hydrated peroxides of iron, of an oolitic and porous structure (not solid like the Cleveland); from their porosity they absorb a very large amount of water, frequently as much as 20 to 30 per cent., including the water in chemical combination. The quality of the ore varies much; its yield may be taken from 35 to 45 per cent. All the oolitic ores are characterised by the high percentage of phosphoric acid which they contain, differing materially in this respect from the brown and red hematites.

There were various other ores used to a smaller extent, viz., the Elba iron ore, which was an anhydrous peroxide of iron, called micaceous iron ore from its structure; the magnetic oxide of iron, which was found only to a limited extent in this country, but largely used on the Continent for making the best qualities of iron; it was generally nearly pure magnetic oxide of iron, and the richest ore of iron known. There was also the spathose iron ore, white carbonate of iron, which made a pecular description of iron containing much manganese. This ore was a white carbonate of iron, and used on the Continent for making the iron known as Spiegeleisen; it was also known as Stahlstein or Steelstone. The following Table shows the composition of these ores.

TABLE II.—*Analyses made by the Author.*

	Iron Ores.									Cinders.				
	Magnetic Oxides.			Elba.	Whitehaven.		Cornish.		Llan-trissant.	Finery.		Forge.		Mill.
Silica	2·80	2·33	13·79	·34	5·78	21·05	36·03	25·97	34·40	25·77	33·33	7·71	8·32	28·71
Peroxide of Iron ...	63·15	67·78	52·02	99·36	93·35	77·56	51·87	69·38	59·05	—	—	8·27	13·53	—
Protoxide of Iron ..	13·23	29·05	22·80	—	—	—	—	—	—	65·52	54·94	66·32	57·67	66·01
Peroxide of Manganese	17·88	·05	·26	—	—	—	·43	—	·09	*1·57	2·71	1·29	·78	·19
Alumina	—	—	—	—	·40	1·54	4·01	4·05	—	3·60	5·75	1·63	1·88	2·47
Lime	·57	·50	7·94	—	—	·53	·43	—	·25	·45	1·19	3·91	4·70	·81
Magnesia	2·34	·26	2·05	—	—	—	·17	·37	·28	1·28	·50	·34	·26	·27
Phosphoric Acid ...	—	—	—	·09	·12	·19	·49	·05	·14	1·37	·99	8·07	7·29	1·22
Moisture	—	—	—	—	—	—	·80	—	·24	—	—	—	—	—
Combined Water ...	·48	·21	·31	—	—	—	5·80	—	6·14	—	—	—	—	—
Sulphur	—	—	·13	—	—	—	·08	—	·05	·23	·10	1·78	2·57	·11
Iron	—	—	—	—	—		Copper ·05	—	·04	—	·17	—	4·50	—
	100·45	100·18	99.30	99·79	99·65	100·87	100·16	99·82	100·68	99·79	99·68	99·32	101·50	99·79
Metallic Iron	54·49	70·04	54·15	69·50	65·30	54·29	36·30	48·56	41·30	50·96	42·70	57·37	58·04	51·34

* Protoxide of Manganese in the following columns.

There is also appended to the preceding table the analysis of the various cinders from the finery, the forge, and the mill, which are all returned to the blast furnace (except in some works where they make a first class description of bar or plate iron, in which case they are generally sold to other works), for the manufacture of a lower class of iron. Cinders can only be used to a limited extent, as they always reduce the quality of iron from the high percentage of sulphur and phosphorus they contain, they are occasionally worked alone on a furnace for the manufacture of ballast iron for ballasting ships, this iron which is exceedingly weak, is known by the name of kentledge.

The author having described the various ores used in this country, then proceeded to consider the fuel, which, in his opinion, was of even greater importance than the ore.

It was only in certain districts that the coal could be used raw When coal was used raw, or mixed with coke, its mechanical condition was of great importance, as it was necessary that it should bear the weight of the materials without crushing, and also that it should not decrepitate; as the latter property made anthracite a less valuable fuel than it otherwise would be for iron smelting. The author referred to the following Table of analyses of coals from various districts.

TABLE III.

Analysis of Blast Furnace Coal, by the Author.

	Welsh.				Staffordshire.	
	1.	2.	3.	4.	Coal.	Coke.
Carbon	89·50	88·13	87·62	82·60	76·32	85·14
Hydrogen	4·37	4·51	4·34	4·28	5·18	·78
Nitrogen	1·25	1·41	1·13	1·28	1·38	1·24
Oxygen	3·14	2·94	2·53	3·44	10·74	
Sulphur	·54	1·01	1·06	1·22	1·01	2·16
Ash	1·20	2·00	3·32	7·18	5·37	10·68
	100·00	100·00	100·00	100·00	100·00	100·00

TABLE III—Continued.

Ashes of Blast Furnace Coal, by the Author.

	1.	2.	3.	4.	
Silica	35·73	24·18	37·61	39·64	*1. Dowlais Upper 4 ft. Coal.
Alumina	41·11	20·82	38·48	39·20	2. „ Ras Gas.
Peroxide of Iron ..	11·15	26·00	14·78	11·84	3. „ Bargoed Big Coal
Lime	2·75	9·38	2·53	1·81	4. „ Tomo Yard Coal.
Magnesia	2·65	9·74	2·71	2·58	
Sulphuric Acid ..	4·45	8·37	·29	—	
Phosphoric Acid .	·99	·21	2·00	3·01	
Sulphur	—	·14	—	—	
Iron	—	·24	—	—	
	98·83	99·08	98·40	98·08	* These numbers refer to both Tables, and allude to the same Coals.
Metallic Iron ..	7·80	18·58	10·30	8·28	

When the coal is bituminous, it has to be coked; or, if only moderately bituminous, some may be mixed with the coke in the blast-furnace. The question of coking was of great importance. It could, however, be only touched upon briefly. Formerly coal was coked in open clumps, but now ovens are more generally adopted, as the yield is much better, and small coal may be coked. The author did not think that a very hard coke was essential for iron-making. It was only necessary to have it sufficiently hard to prevent its being crushed in the furnace.

The question of the ash in the coal was of great importance, as from its being in intimate contact with the carbon of the coal, and necessarily exposed to a high temperature, the various ingredients it may contain are under the most favourable circumstances for reduction; and any remarks made on the impurities contained in the ore will apply with double effect when they exist in the coal-ash. Besides this, the state in which they exist as to their chemical combination was of great importance. Thus coal contains sulphur as iron pyrites, and sulphur in a free state, or combined with the carbon in some way not understood. The former is far more likely to alloy with the iron than the latter, as the greater portion of the free sulphur would be volatilised,

whereas one-half of the sulphur in iron pyrites would still remain with the iron.

The author then proceeded to describe the quality of iron that the various ores made when the furnace was in normal working condition. The clay ironstones unquestionably made a very superior quality of iron. This was due partly to their containing no free silica as sand or quartz, but the whole of the silica, or nearly so, existed in combination with alumina as clay. Besides this it contained a moderate amount of lime, magnesia, and a little potash, which, by the addition of a small amount of limestone, form a readily-fusible flux. The ore containing a little phosphoric acid made the iron work easily and not redshort. The tendency of the hematites was to make an iron of a siliceous character, as the ores generally contained quartz, and no alumina, or very little, and only traces of lime, magnesia, &c. The ore also being free from phosphoric acid, the iron was generally redshort. There are a few brown hematites which are calcareous, but they are generally siliceous.

The oolitic ores were distinguished by the high per-centage of phosphoric acid that they contained, as a rule, and the cold short, nature of the iron made. The Cleveland ore contained an excess of alumina, which had the effect of making the cinder from the furnaces less fusible. This had been obviated by mixing siliceous ores with the oolitic, or, in some cases, by adding silica as sandstone to the blast furnace, for which there was a patent. This, however, required great caution.

The Northamptonshire and Wiltshire oolitic ores differed much from the Cleveland. They contained an excess of silica, and made a pig-iron containing both a high per-centage of silicon and phosphorus. Before the railway system was developed to its present extent, it was always considered that the ironstone should be carried to the coal; but, partly by increased facilities of communication, and partly by improved manufacture, it has in many cases been found more advantageous to carry the coal, as coke, to the iron ore, and recently large works have been established to smelt the ore *in situ* in Cumberland and Lancashire, and Northamptonshire and Wiltshire. Pig-iron is made at these works at a much cheaper rate than from ores of the coal measures, and it is only by the use of large quantities of foreign ores,

and finery and forge cinders, that the Staffordshire and Welsh works can at all compete with them.

In the Cleveland district the supply of coal is brought from Durham, and it is only by the superior quality of the Welsh and Staffordshire coal and its lower cost, that these works can at all compete in making bars with the Cleveland district. In pig they cannot at all compete, as regards cost, either with this district or the Lancashire, Norththamptonshire, or Wiltshire.

When several kinds of iron ores are used, as is the case at the Welsh works, by the judicious mixture of them, any pecularity in the quality of iron, which an ore may produce, may be much modified. The author thought that the best results would follow by using the Cleveland ores with siliceous hematites. The cost, however, of the latter, in comparison with the former, is so great, that they can only be used in Cleveland to a limited extent.

Much had been said and written on the hot-blast, and the opinions on it were much at variance. The author did not think that it injured the iron to any extent when the furnace was in proper working order, and certainly its benefit, by reducing the yield of coal, far outbalanced any difference in the iron; hot-blast iron was in fact, more adapted for some castings than cold-blast. There are some valuable experiments on this point published in a small work by Mr. Fairbairn, on the manufacture of iron. The author thought that, in many cases, a greater saving had been ascribed to the hot-blast than really took place; and that the greatly increased makes of many furnaces must be ascribed partly to the better burden or proportion of materials in the furnace, increased pillar of blast, and improvements in filling.

The shape of the blast furnace was next considered. This differed much in various localities, each works having, in many cases, a pattern of its own; it depended a great deal on the ores smelted, and the fuel used; where coal was used, the furnaces were generally larger at the throat or top. A diagram was exhibited, showing a form of furnace which had worked remarkably well on a mixture of coal and coke, and mixed iron ores and cinders.

It would naturally be supposed that a furnace, by working, would work itself into the best form for smelting. This was not, however

the case, as many furnaces that had always worked well were found, when blown out, to be very large in the hearth, having increased from 6 or 7 ft. (the usual size) up to 12 ft., which certainly was not a good shape. Much depended on the filling a furnace, and its regular working; when this was not the case, the hearth, or bottom of the furnace would rise frequently one or two feet, and, unless this was got down, the furnace never would work well. Great care should always be observed in making the hearth solid, so that it would not rise. The best material was conglomerate, but this, from its hardness, was expensive, and generally large dovetail bricks were used; the hearth being put in before the boshes or lower part of the furnace, which was always built independent of the furnace itself, and rested on the hearth.

The pillar of blast at the various works differed much. Formerly the pillar was not more than from 1½ to 2 lb. per square inch, but this had been gradually increased up to 4 lb. and even 5 lb. per inch, and practice has shown that the higher the pillar of blast the larger the make of iron, the same materials being used. When there is an excessive pillar of blast, and the furnace is what is called driving, the quality of the iron is as a rule reduced, and, at the same time, the yield of coal and limestone (the furnace working on a scouring cinder containing an average of four or five per cent of iron).

It was thought very questionable whether this driving, as practised at some works, was desirable; at the same time, the author thought a furnace might be made to work on a cinder, inclining to grey, which would make a very fair quantity of iron, and it would prove much more profitable when taken to the forge than pig made when the furnace is working on a scouring cinder.

The greater the pillar of blast and the hotter it is the less will be the quantity of limestone used, as a furnace will not drive when it is heavy in limestone.

One of the greatest improvements since the introduction of hot-blast is the application of the waste gases, from the tunnel head of the blast furnace, for heating the blast and raising steam. The advantage of this is now generally acknowledged, although prejudice has hitherto been very great against it. Many works, having tried it and abandoned it

have recently tried it again, and from the good results they have obtained, acknowledge not only its great saving, but the great advantage it has in not only heating the blast better, but in raising more steam than can be effected by any amount of firing.

The plan usually adopted is to close in the top of the furnace with a cup and cone, the cup being 6 ft. 6 in. at the bottom, inclining at an angle of 35 deg., the cone 7 ft. 6 in. at the base, inclining at an angle of 40 deg. A cone of the above dimensions has been found to work very well; the cone is depressed by a counterbalanced lever. Besides covering in the top of the furnace, the author considered that the cup and cone was the best form of apparatus for filling the furnace. In an ordinary open top furnace the materials are charged by barrows into the centre of the furnace, the consequence being that the materials assume a conical shape, all the lumps rolling to the sides where the blast always has a tendency to creep up, thus increasing that tendency by giving it a freer channel, whereas in the cup and cone system of filling the materials were spread by the cone to the sides of the furnace, and the lumps rolled into the centre, thus making a channel for the blast to come through, and the furnace necessarily works better. In some cases the furnace top is not closed at all, the gases being brought down through orifices in the brick-work below the charging plate, or in other cases a cast-iron tube is simply let down in the furnace.

The gases are brought down in a tube below the charging plate. One 3 ft. in diameter is found sufficient for two furnaces. If it is larger, the dust, which is always brought down with the gases, is apt to accumulate. The gases are then conveyed, generally by wrought-iron pipes, to the boilers, and to the hot-blast stoves, where it is mixed with the requisite quantity of air through holes in the brickwork, or perforations in iron doors. The dust which is brought with the gases is apt to adhere to the boilers and the flues, and they require cleaning occasionally. In most cases, when the gases have been brought down, the heat has been so much greater than by the old system of firing, that the stacks have cracked, and, in some cases, it has been necessary to replace them.

The author exhibited the following table of the analysis of the blast-furnace cinders made on an equal weight of cinder taken from

TABLE IV.—*Analysis of Blast Furnace Cinders, by the Author.*

	1.	3.	4.	5.	9.	10.	11.	12.	13.	14.	15.	16.	18.	Mean.	Average of 13 Furnaces.	A.
Silica	39·09	42·52	41·30	44·88	42·08	43·68	42·45	41·08	45·23	42·57	40·02	40·69	38·48	41·85	43·07	40·04
Alumina	17·14	14·96	16·21	15·51	14·19	16·25	14·30	13·65	11·55	13·12	14·71	14·82	15·13	14·73	14·85	12·69
Protoxide of Iron	2·07	3·62	2·65	6·91	2·35	1·33	2·04	1·29	3·08	3·48	2·52	2·19	·76	2·63	2·53	7·81
Protoxide of Magnesia	1·15	1·50	1·10	1·67	1·59	1·15	1·22	1·02	1·02	1·18	·91	1·62	1·62	1·24	1·37	1·12
Lime	31·95	30·04	30·55	23·81	31·55	28·57	30·89	34·32	32·09	31·35	32·27	32·60	32·82	30·99	28·92	32·36
Magnesia	4·31	3·95	4·42	4·38	4·67	4·42	5·32	4·65	3·78	4·44	5·47	4·63	7·44	4·76	5·87	1·65
Potash	1·98	2·06	2·26	1·98	1·73	2·21	2·04	1·75	1·53	1·79	1·72	1·71	1·92	1·90	1·84	1·28
Calcium	1·64	·85	1·20	·59	1·37	1·29	1·04	1·22	1·04	·89	1·31	1·29	1·23	1·15	1·01	·77
Sulphur	1·31	·68	·96	·47	1·10	1·04	·83	·98	·83	·71	1·05	1·03	·99	·92	·89	·61
Phosphoric Acid	·22	·41	·13	·43	—	·10	·10	—	—	·17	·25	—	·15	·15	—	1·08
	100·86	100·59	100·78	100·63	100·63	100·04	100·23	99·96	100·15	99·70	100·23	100·58	100·54	100·32	100·35	99·41
Metallic Iron	1 61	2·81	2 06	5·37	1·81	1·03	1·58	1·03	2·39	2·70	1·96	1·70	1·57	2·04	1·97	6·08

Furnaces 1 to 16 on Common White Forge Pig. Furnace 18 on Foundry Iron. Nos. 1 to 18 represent the Nos. of the 13 Furnaces in Blast at the Dowlais Iron Works at the time the Cinders were taken for the analysis.

"Mean" is the mean result of the 13 Furnaces.

"Average result of 13 Furnaces" is the analysis of a mixture of equal weights of Cinder taken from every Furnace on one day.

"A" is the analysis of a Scouring Blast Furnace Cinder showing that when the Cinder contains much Iron Phosphoric Acid is present in much greater quantity.

every furnace (thirteen in number) every day for a week, the portions from each furnace being intimately mixed together and then analysed. He considered, in many of the analyses hitherto published, that the iron was far too high, and that the quantity run away at the various works in the cinder was not so large as generally supposed. He had carefully gone into this subject, and found that, in previous analyses, manganese was frequently neglected, also titanic acid, which, the author was prepared to show, was an ingredient in all clays and shales, and in most iron ores, although from the very great difficulty of even detecting it, much more determining it, had hitherto been passed over and weighed with the iron, and, in some cases, manganese was weighed with it.

On inspecting the analyses it would be found that, practically speaking, all the phosphoric acid alloys as phosphorus with the iron, and that only when the furnace is on a scouring cinder containing some amount of iron do you not get any quantity of phosphoric acid in the cinder.

June 3rd.

R. M. CHRISTIE in the Chair.

ON THE MANUFACTURE OF IRON.—*Continued.*

By E. Riley, F.C.S., late of the Dowlais Iron Works.

The various qualities of pig iron were considered; they were known in commerce by the Nos. 1 to 6, Nos. 1 to 3 being foundry iron, and Nos. 4 to 6 grey forge iron; besides these there was also mottled and white pig. No. 1 iron was only produced when the furnace was in the best working order, and required a heavy burden of coal and limestone; it was consequently, the most expensive iron to produce; any little irregularity in the blast-furnace soon reduced the iron to the lower numbers, at the same time altering the cinder, which was very grey when No. 1 iron was produced.

On referring to the analysis of various qualities of pig iron (from No. 1 to 6) see Table 5 A, it will be seen that the per-centage of silicium is directly as the quality of the pig, being the highest in No. 1, and lowest in No. 6; whereas the sulphur is inversely as the quality of the pig, being the lowest in No. 1, and highest in No. 6. The phosphorus is a constant quantity. The samples of pig analysed were made from

the same materials, see Table 5 B. The carbon does not differ very materially in quantity in the grey iron, but as you get on to mottled and white the carbon then becomes either partially or wholly combined with the iron, whereas in very grey iron the carbon all exists as graphite.

TABLE 5 A.

Analysis by the Author of Grey Pig Iron from Oolitic Iron Ores.

Silicium, Sulphur, and Phosphorus only determined.

	Silicium.	Sulphur.	Phosphorus.	
No. 1.	4·717	·036	·867	Foundry.
„ 2.	3·659	·077	·917	
„ 3.	3·909	·096	·968	
„ 4.	3·140	·196	·724	Forge.
„ 5.	2·257	·160	·926	
„ 6.	2·197	·248	·898	

Grey Pig Iron from Oolitic Ore (different District to the above).

No. 1.	3·21	·044	1·806	Foundry.
„ 5.	2·67	·081	1·853	Forge.

TABLE 5 B.

Welsh Pig Iron.

	1.	2.	3.	4.	5.	6.
Silicium	2·16	2·22	1·96	1·21	1·14	1·09
Carbon	3·14	3·05	2·90	2·71	2·25	2·37
Iron	94·56	94·34	95·39	95·10	98·87	95·58
Phosphorus . .	·63	·63	·63	·64	·82	·76
Manganese . . .	·50	·33	·23	·14	·17	·22
Sulphur	·11	·09	·04	·46	·77	·73
Nickel & Cobalt	·05	·07	·04	·03	—	—
	101·15	100·73	101·19	100·29	·02	100·75

No. 1. . . . No. 5. Furnace Cold Blast Grey Mine Pig Iron.
„ 2. . . . „ 18. Do. Hot „ „ „
„ 3. . . . „ 5. Do. Cold „ Mottled „
„ 4. . . . „ 5. Do. „ „ White „
„ 5 & 6. . White Forge Common Pig Iron.

When the sulphur is present to any extent in an iron ore it is difficult to obtain grey iron, and when it is in large quantity it becomes almost impossible, unless it be mixed largely with other ores, the effect of sulphur on grey iron being to liberate the carbon, and reduce the quality of the iron. Experimentally, if sulphide of iron be mixed with grey iron graphite is separated, and if the sulphide of iron is used in any quantity the iron becomes white; thus it is that finery and forge cinders always make, when used alone, a white iron, from the high per-centage of sulphide of iron they contain.

In considering the quality of grey pig-iron for foundry purposes, it must be admitted that the chemical composition of the pig is not necessarily an indication of its strength; and it is always necessary that its physical condition should be considered, although as a rule, which generally holds good, you will find that pig-iron which contains a high per-centage of silicon is weak, and more especially so when, besides this silicon, the iron contains a high per-centage of phosphorus, as the pig-iron in Table 5 A and B, which is generally the case in iron made from the oolitic ores. The sulphur cannot be present to any extent in very grey iron; it never exceeds, and is generally below, ·05 per cent. in No. 1 and No. 2 foundry pig. Pig-iron after being remelted is generally increased in strength. This is due more to an alteration in its physical condition than to any chemical change, and is probably due to the iron becoming more homogeneous and uniform throughout. It has been found practically that a very siliceous iron by being remelted was greatly increased in strength, without in any way altering its chemical composition.

It would naturally be asked, has the chemical composition of pig anything to do with its strength, and is not its physical condition the main point? The author considered that the chemical composition was of great importance; at the same time he admitted that the composition of pig-iron was not well understood, more especially as to the way in which the various elements existed and were combined. He also thought that some elements existing in pig had hitherto not been detected; he had himself, in several instances, detected titanium, which, he believed, had not been found before. Again, the elements in pig-iron—more especially carbon and silicon—were capable of existing in very different states, known to chemists as allatropic conditions (or the same element existing in a different physical state, and

not unfrequently playing a different part in combination). Thus we have carbon as the diamond, graphite, and charcoal; and we have yet to learn, not only in what condition the two elements above named exist in various qualities of iron, but also, from the great similarity in many of the properties of them, whether they may not in fact, replace to some extent, each other; and thus, possibly, you may have silicon playing the part, and, in fact, become equivalent to carbon in certain cases.

It has recently been shown, by Professor Brodie, that carbon has, or ought to have, three different atomic weights, and you may have carbon existing in its three states in the various qualities of pig, altering it physically, and differing only chemically, in the aggregation of its atoms, the actual amount of carbon being identical.

Undoubtedly as our knowledge and experience increases we shall be able to give more satisfactory reasons than we can at present, as we are only able to draw general conclusions which the author considered to be, as a rule, correct.

Pig-iron from various localities was then considered, the Welsh being generally noted for its strength. It was not so fluid as the Scotch and Staffordshire, which was more adapted for light castings. The general effect of silicium and phosphorus was to make iron more fluid, but to diminish its strength. The hot-blast iron was also considered more adapted for some castings than others.

Various processes were noticed for toughening pig-iron, which generally consisted in reducing the impurities by a process of refining or oxidation, or mixing wrought iron or metal with the pig.

The treatment of the pig in the refinery and the construction of the latter were next considered. Formerly the pigs were re-melted in the finery, but in many works the iron was run direct from the blast furnace into it. White pig was much more easily blown than grey pig; the former quality was generally used in Wales for rails and bars, and it is only when the very best quality of iron is made that grey pig is used.

The finery has, however, in many works been superseded, and the pig is taken directly to the forge and puddled. When pig is used in the forge it is called boiling; when metal puddling, in some works it is still found advantageous to use the finery partially, and it is only when the pig is of good quality that it can be done away with altogether.

The author then referred to diagrams of the puddling-furnace, and noticed the great improvement that had been effected by the use of cast iron bottoms. They were generally $1\frac{1}{4}$ to 2 in. thick, and rested on iron bars so as to allow the air to keep them cool. In boiling pig, the action of the iron and cinder (which was much more fluid than in puddling) was very great on the sides or boshes of the furnace, and great difficulty was experienced in keeping them intact. Limestone had been found to stand better than anything else, although it made the iron redshort, and was objectionable on this account. Red ore had been used, and a mixture of red ore, hammer slag, and lime with more or less success; also spathose iron ore had been found to stand very well, and in America steatite or soapstone, had been used successfully. Some works had a mixture of their own, which was kept secret, but generally consisted of red ore, hammer-slag, and lime in various proportions. The maintenance of the boshes of the puddling-furnace was of great importance in an iron works. In Staffordshire calcined tap cinder was used for the bottoms of puddling-furnaces.

The various qualities of pig, and their working in the forge, were next considered; in Wales, where white pig-iron was used, there were two, perhaps three, varieties, which worked very differently in the forge. First, you have what is technically called strong iron. This iron is more or less siliceous, and casts solid with a convex face when cast in sand or ashes; with a cencave face, when cast in chills (cast iron moulds). It is very sonorous, and rings like a bell when struck and breaks with a perfectly solid white and crystalline fracture. This is the best description of white forge iron and will make bars or rails of excellent quality.

The next description of white forge iron is when the pig contains a high per-centage of sulphur and phosphorus; the iron is then thick, and runs into the chills or sand with a very rough face covered with warty excrescences, strikes dead like lead when struck, is frequently not solid, and is of a dark white colour; this iron is known as weak iron, and is always produced from finery and forge cinders, when they are used in any quantity on the blast-furnace.

When very siliceous iron ores are used the tendency is to get a siliceous pig. Finery and forge cinders do not, as might be anticipated, make a siliceous iron, except when they have been calcined and rendered infusible.

In some cases you have pig-iron siliceous and weak at the same time

from the presence of sulphur and phosphorus. The pig is then of the worst possible kind.

Siliceous pig-iron is much more difficult to refine or puddle than weak pig. The author mentioned a case where white pig-iron, containing 3½ per cent. of silicon, was blown for seven hours in the finery, and was not then refined; this pig when puddled, worked to a yield of 27 cwt. of pig to a ton of puddled bar, and after two heats the men would not work any more. It was found in practice advantageous to mix the strong pig with the weak in the forge. The author considered that silicon to a certain extent in forge pig was advantageous. He found that the best white forge pig contained from 1 to 1½ per cent.; also pig made wholly from Welsh mine contained the same amount. This percentage of silicon gave what was known as strength to the iron, but when the silicon exceeded the above-named proportion, then the iron became difficult to work; the effect of the silicon was to retard the puddling process, and thus it gave time for the impurities to be more completely separated.

The skill of the puddler was of much importance, and the author warned all engineers not to rely on single experiments made on the yield of pig-iron. The only way to get at the true result was to take the working of a whole forge.

The average quantity of coal used to make a ton of puddle bar in Wales was 17 cwt, in some cases less, and the quantity of pig from 22 to 23 cwt.

The next point considered was the mechanical treatment of the iron. This the author considered a very important one, and quite irrespective of its chemical composition. In most works in Wales the squeezer is used, and in some works a patent squeezer, consisting of three grooved eccentric rollers. The latter was considered preferable to the former. The other mechanical means of compressing the iron were the old tilt-hammer and the steam-hammer. Formerly the old tilt-hammer was the only means of compression used, but since inferior iron has been made by driving the furnaces and using the forge and finery cinders and impure ores, the iron would not stand the old tilt, and the squeezer was introduced, by the use of which almost anything can be shingled into a bloom and passed through the rolls, whereas with the old tilt-hammer, the iron from the first has to bear the full weight of the blow. This does not apply to the steam-hammer, as with it the blow can be regulated to any nicety.

Lately engineers, in their specifications, have stipulated that the iron shall be hammered, and not squeezed; and the plan has been adopted of doubling the puddle balls by slightly hammering them, placing them one on the other, and welding them into a slab, for the head of the rail; this makes the rail-head crystalline, and not fibrous, as it is only once submitted to the drawing action of the rolls.

The iron, after squeezing or hammering, is passed through the rolls, and rolled into No. 1 iron or puddle bar, which is cut by shears into the requisite lengths for the subsequent pile.

The different methods of making the various piles for rails, &c., were entered into, the great object in piling being to get the pile as solid as possible, and free from interstices. The piles were frequently made of puddle bar of different widths, piled alternately, so as to break the joints, and also, in some cases, the puddle bar was cut in short lengths equal to the width of the pile, and each layer piled at right angles to the previous one. This had a tendency to make the iron less fibrous.

The various sections of rails in use were then alluded to. The double-headed rail genearlly was made with slabs at the top and bottom of the rail. For the best quality of rails they were about 2 in. in thickness, and the rails were double-heated. Some engineers had their rails made of three hammered slabs, one piled on the other.

In rolling the flange, or American rail, a particular description of cold short iron was made for the flanges to stand the strain that there necessarily must be, from the rails being rolled edgeways, and the flanges not travelling at the same speed (from the less periphery of the rolls), it was necessary that the flange portion of the rail should slip; and partially on this account, and also on account of the flange becoming colder than the mass of the rail, it was difficult to obtain a perfect flange, unless a peculiar description of iron was used. This iron was made generally with forge cinders and Welsh ironstone, without any red ore. In the bridge rail, which was rolled flat, head up and down, the iron was only likely to rip by becoming cold, and was not submitted to so great a strain as with the flange rail. For common American rails, the slabs for the heads were frequently not made more than $\frac{7}{8}$ in. thick, and the rails were only single-heated.

The way in which a rail has been piled, and the thickness of the

top slab for the head, may be easily determined by filing a section of the rail smooth, and acting on the surface with dilute mineral acid, which dissolves the iron, and leaves the cinder in the welds or joints intact.

Rails being submitted to a different strain to other descriptions of iron, it was soon found that the fibrous iron, such as is used for making cable bolt, was not adapted for them, as the iron was too soft, and strips or ribbons soon began to pare off the rails. Various means have been adopted to make iron crystalline and hard. As a rule, the more you roll iron the more fibrous it becomes up to a certain point, and for this reason many engineers have the slabs for the heads of the rails hammered, so that they may only be submitted to the drawing action of the rolls once. Since the introduction of the oolitic iron ores, it has been found that, by smelting them with a mixture of a little cinder and clay ironstone, that a peculiar description of cold, short, crystallised iron is produced, and this iron has been very largely used for the manufacture of the heads of rails. The pecular description of this iron is due to the phosphorus which the oolitic ores contain. Phosphorus has the property, when alloyed with iron, of making it work soft and cold short.

Rails made with this iron have been very favourably reported on by engineers. The iron, although hard, is very weak, and the author's opinion was, that hard iron might be made with equal advantage by the use of manganese, without, at the same time, reducing the strength, as you do when phosphorus is present.

Some foreign engineers have even gone to the length of making it a clause in their specifications for rails that they shall break when a given weight is let fall upon the rail resting on bearings at a specified distance apart.

Single-heated rails require about 12 cwt. of coals to the ton, on an average, and double-heated about 16 cwt.

The author, after apologising for the very brief way in which he had considered the various processes in the manufacture of iron, next proceeded to consider some of the recent improvements that had been suggested and carried out for the manufacture of iron and steel.

The most important, perhaps, was the Bessemer process, which, when first put forth by Mr. Bessemer, in 1856, caused quite a sensation in

the trade. The author was, at that time, at the Dowlais Works, and made a series of experiments on the process, which were detailed. The results of the experiments were, that only from the very best descriptions of foundry iron could wrought iron be produced which had at all the character of ordinary bar iron, and even this was of a peculiar crystalline structure, and had the appearance of burnt iron. When the ordinary forge pig, used for making bars and rails, was operated on, nothing could be done with it at all. The iron, after blowing and casting, when submitted to the action of the squeezer, crumbled all to powder and dust; and it was only by using very great care that a piece was made into a bloom and passed through the rolls, the bar was as brittle as glass, and broke, when struck, in all directions, longitudinally and transversely. The same results as the above were obtained by experiments at various other works, and only when such pig as the best Blaenavon Foundry, foreign pig, or pig made from spathose iron ore was used, that any good results could be obtained.

The author investigated the cause of the failure of the process and, on analysing samples of the pig, and the iron after blowing, he found that the whole of the carbon and silicon had been separated absolutely, as not a trace could be found; whereas the sulphur was only slightly diminished in quantity, and the phosphorus, if anything, increased. From the above, it was evident that the non-separation of the latter elements was the cause of the failure, in a great measure, with ordinary white forge pig.

Mr. Bessemer instituted a series of experiments on his process, and erected works at Sheffield to carry it out practically. He soon found that he had been in error in using some of the best description and highest priced irons, as there were others in the market which were far cheaper and much more adapted for his process. On analysis, it was found that the grey pig made in Cumberland and Lancashire, from the red hematites, was nearly free from sulphur and phosphorus, containing not more than ·05 per cent. of the former and ·10 per cent. of the latter. This iron is very siliceous, but by blowing the whole of this is separated; by blowing this iron, and adding, after the blowing, some metallic manganese, or an alloy of iron and manganese, iron or steel of any quality could be made. The author, before considering the condition in

which he considered the Bessemer iron to be, detailed more experiments he had made on wrought iron in a fused state.

The results of the experiments (which had been frequently repeated) were, that if the very best fibrous cable bolt iron was melted in a clay crucible (so as to be kept away from carbon), a crystalline fused button was obtained, which had somewhat the appearance of antimony. This iron, when worked by a smith, was very redshort, and after welding, it broke all to pieces as the heat came down, although at a low temperature it worked tolerably well. It was in fact, in the same condition as the Bessemer iron, and was, in this state, useless. On adding to the pieces of iron (from 1 to to 1½ lb. were used in each pot) a very small amount of metallic manganese, from 1½ to 3 or 4 per cent., in various experiments it was found that the lower quantities of manganese restored all the original properties to the iron, and that anything could be done with it, and it would work at all temperatures. The higher proportions of metallic manganese gave the iron a steely character, and in fact converted it into a low steel. Experiments were also detailed on the reduction of wrought iron in a fused state direct from the best clay ironstone (by leaving an excess of oxide of iron in the cinder); the iron thus produced was useless, as it would not work at a high temperature, but worked moderately well at a low heat.

The author considered that a small amount of carbon was essential to wrought iron, and by the process of melting or the Bessemer process, this small amount of carbon was removed. By the introduction of metallic manganese, the carbon was taken by the iron, and the manganese would become oxidised, and unite with the silicon or other impurities in the iron. It was well known that pig-iron made from the spathose iron ore, not only contained a high per-centage of manganese, but also a higher per-centage of carbon than any other description of pig. This iron was generally white the author never having seen it better than mottled, and he believed great difficulty would be experienced in getting it grey. Manganese certainly has the property of fixing carbon in iron in some way not very well understood, and when this metal is alloyed with iron he considered that the manganese would be completely separated before the carbon was touched, and in its separation the oxide of manganese being an excellent flux, it would have a tendency to separate the impurities in the iron.

The reduction of manganese from its ores, and the difficulties attending it, were mentioned in illustration of the properties of this metal, and the author considered that the application and use of manganese in the manufacture of iron was most important.

The author then referred to drawings of the vessel Mr. Bessemer used for his process. One of the great difficulties was in getting the tuyeres to stand, as the fluxing action of the oxide of iron and the temperature in the blowing vessel was very great. In several instances a whole fire-brick had been fluxed away in twenty minutes. By using powdered sandstone, known as "ganister," the fluxing action was not so great, and a further improvement had been made by intrdoucing the tuyere from the top, and making it altogether independent of the vessel, so that it could at any time be withdrawn and replaced by a new one.

Various other processes for the manufacture of steel were commented on, amongst others Uchatius', Mushet's, and puddled steel. The author considered that puddled steel was liable to be wanting in uniformity.

Much had been written on the composition of steel, and various theories had been propounded as to its composition and the elements requisite for the production of the best varieties of steel. M. Frémy had published a very extensive series of experiments, and he was of opinion that iron in its three states—cast iron, steel, and wrought iron—is due not only to the different proportions of carbon they contain, but also to the presence of nitrogen. Mr. Mushet again has started a theory that titanium is essential in the manufacture of steel.

It was a well-known fact that cyanides have the property of converting iron into steel, and after the very elaborate investigation of M. Frémy, in which he showed that nitrogen assisted very materially the formation of steel, the author was of opinion that nitrogen might act in a somewhat similar manner to manganese—viz., as a carrier of carbon, but he was hardly disposed to think that nitrogen was a constituent part of steel. The formation of steel with pure carbon and iron was discussed, and it was thought that further investigation was necessary to prove if nitrogen was or was not a constitutent part of the best varieties of steel.

With regard to titanium, this metal had a great affinity for nitrogen and carbon; and if nitrogen is requisite in the manufacture of steel, it is possible it might act as a carrier of nitrogen and carbon. A large sample of

titanium (in a pure state), obtained from the hearth of an old blast-furnace was exhibited.

The author concluded by pointing out the difficulties that there were in accounting for the different varieties of iron which were due, in some cases, to physical, and in others to chemical differences, in their constitution, and at times, perhaps, both combined. It was only by observation and carefully conducted experiments that the true causes could be determined. He was ready to admit that our knowledge was limited on the subject, and he must plead this as an apology for the imperfect way in which he had treated it.

DISCUSSION.

Mr. Parsey observed that he had tested a portion of a steel plate made by the Bessemer process, which proved to have great tensile strength; the section tested being equal to ·3669 of a square inch, and bore a tensile strain equal to 53 tons per square inch, and also a portion of another steel plate, which bore a tensile strength of 30 tons to the square inch. Both plates were made by Mr. Brown of Sheffield, and tested under precisely similar conditions.

Mr. H. P. Stephenson stated that some 1-inch bars of puddled steel broke with a strain of 87 tons to the square inch.

The Chairman observed that the subject had been so fully and ably treated, that little room was left for discussion, a large amount of useful information had been given by the author, which would be of very great benefit to the members of the Society.

September, 1861.

H. P. STEPHENSON IN THE CHAIR.

ON THE UTILISATION OF WASTE MINERAL SUBSTANCES.

By E. Edwards.

The author explained that the object of the paper was not to advance any new theories or processes, nor to attempt to exhaust the wide

field presented by a subject of such interest and importance, but to mention a few of the more important methods which have been suggested or adopted for utilising substances at present either waste or of little value.

Coal, it is well known accumulates in large quantities at the mouth of most pits, in the shape of slack, and in this condition is comparatively useless, on account of the presence of iron pyrites, shale, &c. This may be utilised in three different ways:—1st. by using it as fuel; 2nd. by cleaning it, or otherwise preparing it so that it may be manufactured into coke; 3rd. by mixing it with other combustible substances, and compressing it into suitable blocks, to be used as a substitute for ordinary coal.

Small coal used as fuel unless very fresh, is of little value, as exposure to the air, causes it to lose the gases it contains; but after being washed by some of the processes now employed it may be used not only with advantage, but appears to be specially adapted for the manufacture of the best coke. There are various plans in use for washing coal, the general principle of which depends upon the fact, that the impurities mixed with the coal are of greater specific gravity than the coal itself; and by applying a modification of the method adopted for separating metallic ores, the coal may be separated from the deleterious matters it contains. The difference in the specific gravity of the coal and shale being small, it is necessary that the coal should be either crushed or sifted. The coal when reduced to a uniform size, is allowed to fall upon a perforated plate in the upper part of a cistern supplied with a constant stream of water, which is caused to pulsate or rise through the plate by means of a species of piston driven by machinery, the light and clean coal being washed off the surface of the mass by the stream of escaping water, whilst the shale and pyrites remain upon the plate, and are removed when necessary.

The author had made experiments on this process, and arranged a modification of the machine, in which the coal is removed by self-acting scrapers; and he also found that when the rise and fall of the water through the perforated plate was limited to a vibration of small extent, substances of very nearly the same specific gravity were separated, the shaking of the mass being quite sufficient; this vibration was

effected by forming a part of the cistern with a leather disc protected by a plate against which a succession of cams strike.

In some experiments made with South Yorkshire coal he had found the impurities to be about 2½ per cent. or 56 lbs. per ton, about 35 lbs. of which consisted of iron pyrites, which is by far the most injurious, shale being of rather a negative character. When old slack is used for making coke it is generally mixed with some good coal.

The last purpose to which the waste coal is applied, is the manufacture of artificial fuel, composed of coal, pitch, and other substances compressed by mechanical means, then either dried, baked, or used raw—it is necessary that good coal, or washed coal should be used for this purpose. Another plan of utilising small coal has been patented by Mr. Wood, which he calls patent preserved coal, the main difference from the above being that the coal of which it is composed is either coked first, to drive off the gas and volatile substances contained in it, or this process is effected after the component parts of the fuel have been mixed and moulded into blocks, the specific gravity of which, when formed, is greater by one half than that of the coal.

Bearing a near relation to the heaps of waste coal at the pit's mouth are the heaps of waste mineral matters containing ore, which lie at the mouths of mines. The utilisation of this waste mainly depends upon the per-centage of mineral matter it contains, and we can only aim at the gradual improvement in the means of extracting the small quantity of valuable ore which is allowed to remain in the waste.

The slag or dross formed in smelting iron and other metals, is produced in immense quantities, and has been hitherto only partially used, this applies more especially to iron slag, which varies much in different localities, being in some of a black or dark colour, of little pretensions to ornamental purposes, whilst in others it has most beautiful shades and tints. Various experiments have been made on the utilisation of the latter material, by casting it in moulds, and carefully annealing it; great difficulty is found in accomplishing this successfully, the articles made being of a weak and brittle nature, and incapable of standing changes of temperature. This slag has also been cast in blocks and used to a limited extent for building purposes. Copper and lead slags have also been used in a somewhat similar manner. The great diffi-

culty in the utilisation of any of these slags for such purposes is, that the bricks produced are of such little market value when made, that the cost of moulding and carriage is too great to allow their use except in the immediate neighbourhood where they are manufactured.

The author alluded to another use of iron slag, which was, perhaps, less generally known, viz. in the adulteration of emery which was frequently mixed with the ground black cinder to the amount of from 25 to 100 per cent., more especially in the commoner kinds of emery cloth.

The author proceeded to consider the utilisation of the waste gases from the blast furnaces, which was generally effected by closing the top of the furnace and bringing the gases down to heat the blast, or raise steam. It seems exceedingly doubtful whether it is either expedient or profitable to control the free escape of the gases from the furnace top. Estimates of the value of the gases have generally been made on the assumption that they may be withdrawn without effecting the smelting; practice, has, however, established the fact that their withdrawal occasions an alteration in the economy of the furnaces, so that the policy of withdrawing them for such purposes may fairly be questioned.

He alluded to the use of waste scrap-iron, which was carefully collected, re-wrought, and worked together, and he attributed the good quality of the product to the thoroughly mingling together of the different qualities of iron, and the amount of working it receives.

The paper was concluded by an allusion to Mr. Ransome's method of manufacturing artificial stone from broken and irregular shaped stones, cemented together by a solution of flint in caustic soda.

DISCUSSION.

Mr. P. F. Nursey enquired if the author of the paper could state whether the gossan of copper lodes had been applied to any practical purposes, as he had made several experiments, by which he found these gossans when mixed with oil made a very good paint.

Mr. Edward Riley considered that there was no question as to the

policy and economy of taking the gases from the blast furnace; he was aware that in many instances trials had been made to economise the gases and failed, this was, however, only due to the trials not being persevered in, or in their being improperly made; at the largest iron works in the country, economising the gases had been first tried, and discontinued, but latterly they had again been tried, and the success was most complete, and the saving in fuel very considerable. It was not necessary to close the top of the furnace, the gases had been very successfully drawn from a furnace at Brymbo, in North Wales, by means of a cast iron tube of large diameter being inserted for 7 to 10 feet in the materials at the top of the furnace, and he considered that a modification of the cone of the closed furnaces and the tube would be found most beneficial. Most works were altering their furnaces to economise the gases.

Respecting the iron slag, he had seen experiments made on a large scale to anneal it, but they were unsatisfactory, and it appeared to be exceedingly difficult to get the cinder in an annealed state. Cinder when polished often rivals marble in its markings.

One great objection to the cinder for building purposes was its great specific gravity which increased the cost of transit, and diminished its value as a building material.

Mr. Louch described Mr. Bessemer's method of compressing coal, in which process the small coal is placed in moulds and heated to a temperature sufficiently high to render it plastic, it is then pressed into a solid mass of a density greater than that of the natural coal. The process is very slow and expensive. He also explained the plan adopted by the Aberdare Steam Fuel Company, viz., of compressing the coal by hydraulic pressure, through the medium of an accumulator; this process is now in successful operation.

He also drew attention to an article produced from the lead mines of Derbyshire, viz., sulphate of baryta, which was formerly wasted, but is now used as a pigment, principally in the adulteration of white lead.

Mr. Edwards in reply stated that the oxidation of the Staffordshire slag would entirely depend upon the time it was exposed to the atmosphere. He could not state to what extent the gossan of copper lodes,

by their conversion into a paint, had been practically adopted, or the results obtained.

As regarded compressed coal, besides effecting a saving of about 50 per cent. in its specific gravity, it possessed the advantage of being able to be made into blocks, thus rendering it more portable and easy of stowage on board ship.

The Chairman in summing up stated that the utilisation of waste materials was a large subject, and one that deserved the attention of all. Bringing into practical use, substances that had been previously cast aside as waste, was a great gain to commerce, and would no doubt open a field for many to acquire large fortunes.

October 7th, 1861.

E. RILEY IN THE CHAIR.

ON ARMOUR PLATES.

By T. W. RUMBLE.

In presenting this paper to the Society, the author stated he would especially guard himself against any undue merit or assumption, and rather rest the justification upon a desire to provoke discussion, feeling that it is necessary some attempt should be made to render this important manufacture of thick plates perfect, that we may send forth to meet the enemy, not the wooden walls of Old England, but impregnable iron, and iron-cased vessels which may defy them; and it is by meeting together thus, and freely discussing such subjects, that greater perfection in the arts and manufactures are arrived at. We cannot but feel that this is a remarkable period—it is one, not of private competition, but a competition of nations, and we must feel that, having entered ourselves and made a fair start in this great national race of competition, we are bound to lay our heads together and to take care we, beyond all question, win the race.

In viewing the strength of iron as a material little can here be said. Important progress has of late been made in the adoption by practical men of correct principles as to the action of the particles of a beam in resisting

fracture, the knowledge of which principles had formerly been confined to a few mathematicians. They relate chiefly to the action of the straining force, and its combination with that of the bending force, which latter, at one time, was the only circumstance considered. One of their results is, that the neutral axis of a beam, as it is called, is not, as it used to be described, a place of no strain on the particles, but it is truly a place where although the strain in a horizontal direction, due to the bending force, is nothing, the strain due to the shearing force is a maximum, and consists in a tension in one diagonal direction, and a compression in another, each making an angle of 45 deg. with the horizon.

With respect to the durability of iron ships, a second thought is scarcely necessary, for time sufficient has elapsed to establish the fact that iron ships last longer, fit for service, than those constructed of wood. It was at first thought that the action of salt water would produce rapid oxidation, and hence speedy decay. Indeed this has been we may say the cardinal objection, the stumbling block to the construction of vessels of this most invaluable material. There can be no doubt that, in this respect, we have put on our glasses and magnified the evil. This we are bound to acknowledge, when we find vessels—iron vessels constructed some 15 or 20 years past—still in existence, and what more do they cost to keep in repair than those of wood? They all require an occasional coating of paint or other anti-corrosive matter, to neutralise the effect or action of the atmosphere Ships, like our keys or other bright domestic instruments and implements will keep bright and free from oxidation by use, again when the form of construction is taken into consideration, the many ways we have of bracing and staying the weaker parts, a second thought cannot but prove how infinitely stronger and more durable are vessels constructed of iron.

There is, indeed, a wonderful change in the progress of ship-building, and it may not be too much to say, we are at this very minute, though in transition, labouring to accomplish even the rendering of iron ships of war shot-proof, if we have not already accomplished the same.

It is true, we received the challenge from our friend the Emperor of the French, who had and has an idea of creating an ocean fleet of iron-cased vessels (pre-conceived by Colonel Paixhan in 1821, nearly forty years since), and when they launched the La Gloire, we received the challenge to enter ourselves in a great competitive race for superiority in the construction of

ships of war, and having entered we intend to win, and carry off the laurels, if it be possible to render invulnerable armour-casing for our ships, made from iron or other materials.

Our first experiments for the purpose of testing the resistance of iron pla'e for ships of war against musketry, canister, and grape-shot were performed on the 6th November, 1849, at Portsmouth, under the direction of Captain, now Rear-Admiral Chads. But the question of iron-cased vessels only appears to have been taken into the serious consideration of our Board of Admiralty early in 1859, though the first thick-plate experiment took place on the 21st August, 1858, during the time Sir John Pakington presided over that body; and strenuous were the efforts made by our leading naval architects to design such a vessel as should answer all the requirements of the case, giving speed, stability, and due regard to the fighting qualities necessary. Many and various indeed, were the ideas submitted, embodying a construction for war ships differing materially to any ever before constructed, all the designers keeping in view the fact that, if we are to fight, we must "To arms, and force to force oppose," The result of this great competition was the production of the Warrior, to be followed by the Black Prince, vessels well fitted to bear the flag of Old England and to maintain our supremacy upon the waves of the deep, even were she placed in juxtaposition with the La Gloire. It is unnecessary here to refer to the dimensions, accommodation, or construction of the two ships, for it must be readily admitted they will bear no comparison.

There cannot be a doubt but that at the present time we are, in reference to the construction of our war ships, in a state of transition, and the application of iron or armour casing to fulfil and conform to the necessary conditions is a question that we cannot expect to grasp at once all the anticipated conditions of the problem. Much will have to be estimated by experience rather than by any direct calculation, every experiment rendering the question more and more complex.

A most important consideration is that of the temper of the plate when finished, for we are told in the experiments on the 11th June, of firing from a 95 cwt. 68-pounder smooth bore, at 200 yards range, with 16 lbs. powder: the result of the firing proved the smaller plate to be of too brittle a nature to resist the impact of the solid 68-pounder, but the other large plates of a superior fibrous nature, gave very different results to any plate

that had yet been experimented upon from the solid 68 lbs. shot, and where the plate was struck fairly in its centre by the shot, it made an indentation of 2 inches on the plate's surface, and then dropped off. Three shots struck the plate and fell back from its surface, leaving these 2-inch indentations in a triangular form, with about an 18 inch base. The plate was afterwards struck by two other shots in the area of the triangle, but still it was not penetrated; one corner of the plate was carried away by successive shots striking it in the same place, and two pieces were broken out of its edges, but these could only be considered in the light of unfair blows, as those parts of the plate were without the support they would receive when fixed on a ship's side, in company with other plates tongued and grooved, as is the case with the Warrior and Black Prince's plates. The only instance of the plate being pierced by a single shot, was in its midship part, where it had been placed over one of the Sirius's main-deck ports for the purpose of testing the difference in the effect produced by the solid 68-pounder upon 4½ inch iron plates supported upon a bed of timber; the result being in favour of the timber backing. The fracture of the plate however shewed its toughness and fibrous quality, its splinters being confined to pieces thrown off within a diameter of about 18 inches of the spot where the shot passed through, leaving the plate without any of those fearful fissures that have been so often witnessed in other iron plate experiments.

Nevertheless, the author thought it still became a question of timber backing or no timber backing, and he felt inclined to say—no timber, but let us construct our ships of iron; planting the armour casing on a skin of iron properly proportioned, and the experiments performed on Mr. Fairbairn's target at Shoeburyness on the 30th July, strengthens and carries out this opinion; for though it is true the plate was much battered and doubled up, yet the Armstrong 100-pounder and 200-pounder at 200 yards range did not penetrate the plates.

The target was 10 feet long by 6 feet high, and was constructed for the purpose of ascertaining how far it was possible, by a slight increase in the thickness of the plates, to do away entirely with the expensive and weighty timber backing, and also to do away with the acknowledged source of weakness arising from holes having to be drilled through the plates for the purpose of fastening them to the ship's side; for in nearly all cases

where the plates have been fractured it has commenced from one of the holes.

Many and various are the schemes for fastening these plates together, and many of them are important and valuable, and this is a question well fitted for the discussion of this meeting.

Armour-plate experiments commenced at Portsmouth, in 1856, against H.M.S. Alfred, and targets covered with plates 4 inches thick, formed of metal of various descriptions, bolted by large bolts to the timber, by firing shell and shot, which proved about as serviceable as firing marbles would have done, and has ended, so far, with the solid shot from the 95-cwt. gun.

With this latter weapon experiments have been made upon many 4½ inch plates, both iron and steel; some of which it has smashed at once, and others after a succession of blows, not of necessity upon the same spot. Others have been penetrated by a single shot, as in the case of the "chain" armour, while others have withstood the crash of 68 in a wonderful manner, as instanced by the Warrior's scrap sample plate and the large plate referred to, which may be looked upon as the most successful instances on record at Portsmouth of the resistance offered by 4½ inch plates, placed in a vertical position, to the solid cast iron shot from the 95-cwt. gun.

Many of the experiments performed doubtless lead us to pause, to reflect upon the advisability of constructing an iron-cased fleet, however, although our departments, the dockyards and gun factories, are working against one another, each in its turn getting the upper hand. Though, but a few days since, in the Victoria Dock lay the redoubtable Warrior, on which all the resources of the Admiralty were concentrated, so that she took the water, proof against attack, and the master-minds are employed, just opposite, in the Royal Gun Factory, in manufacturing engines for the destruction of such vessels as the Warrior and her kind, each in its turn gets the ascendancy, and the second success destroys the first; and, although this is the case, yet we have at present no right or premises to condemn the one or the other.

There are many points worthy of consideration and careful experiment, such, for instance, as the class or mixture of iron to be used, its manufacture, its piling, or of alloys that might be mixed with the iron, to give greater toughness, tenacity, and resistance to impact; or to alter its specific gravity, whereby we might get a better and more easy flotation or

displacement. He could not agree with Mr. Fairbairn's remarks at the British Association (on 7th September—Section G); for there he states: "Though we had very good iron in this country, yet he did not think that the quality of the wrought iron was quite so good as some produced in other countries." The iron itself was good, but it had not that uniformity of texture which was obtained in foreign countries; our iron masters were bestowing attention on the subject, and in a short time would, he believed, be able to produce such plates as would have a fair chance of resisting such artillery as Sir William Armstrong's.

In reference to "armour plates" what is our experience, what our experiments, and we may ask what has been the amount of money or time expended upon this all-important subject in comparison? It is but the other day we received the invitation to enter into the competition with our neighbours, it is not what have they done, but the question is—what have we accomplished towards solving the problem of invulnerable armour clothing for our vessels of war? It is true some few schemes have been submitted to the Admiralty Board and its officers, as also to the committee appointed to investigate the subject, and that ideas for the alteration in the form of the vessels have also been submitted, and the form of armour covering to be used so far and so far only as chain cable and plates are concerned, and it were well to ask ourselves, what amount of time, disinterested experiment, and scientific investigation have each and every one of the projectors of the several schemes given to their subject?

Again, what have been the experiments performed at Portsmouth by the Government, beyond firing at a few infantile plates, and some of which have proved a failure, and been condemned, but not for want of quality in the iron, but from the want of suitability to resist the impact and concussive strains of shot and shell? There is no doubt about the soundness of the policy of having a committee to investigate the problem, but it becomes a question for consideration as to whether the combination or mixtures of the iron, or iron and alloys, is not the first thing to be done; we have men fully capable, from practical experience and scientific attainments, to enter into this important and analytic part of the investigation, for we know that there is an immense variety of qualities of these metals, and the question arises, can iron be produced from combinations and alloys, so as to give the required strength to resist the several strains caused by the action of heavy

gun practice at the same time with due regard to the economy in thickness, so necessary to the practical and successful development of the problem. We want that which is strongest, under all conditions, in proportion to its weight, and no doubt a strong light may be thrown on this important question by collecting the experience of the members of this and the like institutions, and those practically connected with our blast furnaces and forges.

In reference to hammered plates, the author stated that under all circumstances he thought them unsuitable to meet the requirements and conditions of the problem. Partly from the fact that these plates are made from scraps, that is to say, of various pieces of iron, necessarily of different tempers and heats, each requiring different treatment to produce proper weldings, and further because the portion of the plates are so jointed together at their ends that they have not that length of fibre or strength of weld which is produced by the process of piling and rolling.

The size and weight of these plates are now pretty generally known to vary from 15 to 20 feet long, and from 2 feet 6 inches to 4 feet 4 inches wide, by 4½ inches up to 6½ inches thick, weighing from 4 to 8 tons when finished, so that one of the difficulties in making armour plates is the great size and weight, together with the heat thrown off from such a mass of material when ready to be finally passed through the rolls, making the manipulations in the working the more difficult and vexatious.

Let us, however, take into consideration the making of a 5 ton plate, which in its embryo state consists of a certain mixture and quantity of pig-iron thrown into the puddling furnace, and then puddled into blooms, and thence shingled and rolled into plates 12 inches wide by 1 inch thick; these are cut up into lengths of about 30 inches. Five of these are then piled, brought to a welding heat, and then rolled into a rough slab; another lot are similarly treated, and these two slabs are welded and rolled down to a plate, which is sheared to 4 feet square by 1¼ inch thick. Four of these slabs are then piled together, and reduced by the rolls to a plate 8 feet by 4 feet by 2½ inches thick; and, lastly, four of these are piled together in a mass, 8 feet by 4 feet by 10 inches; they are then brought to a welded heat in the furnace, the men are marshalled to their posts, and the final operation commences, which consists in passing a chain attached to the tongs, grasping the plate round the rolls in front of the furnace, which is

detached after the plate is finally on the carriage intended to convey it to the rolls, where it is reduced, after passing several times, from about 10 inches to 4½ inches, the required thickness; it is then conveyed by a wrought iron crane to the straightening plate (made of cast iron), where it is allowed to cool, during which time a cast iron cylinder of about nine tons is passed to and fro to remove the curvature produced by the rolls, or in the removal of the plate from the same to cooling plate; the process of cooling takes some eight hours, and as soon as the plate is ready it is conveyed to the planing and slotting machines, and there trimmed to within 1 inch of its final size when fixed.

One of the great difficulties with rolled plates is the liability to lamination, and he feared by the present process of rolling it would be some time before this difficulty could be overcome. Lamination and brittleness must be avoided, and the author's own feeling was that the plates would yet have to be made by the Bessemer process. He felt convinced if proper attention be given to the subject, and the necessary mechanical appliances brought to bear in the manipulation of manufacture, plates so made will supersede the rolled and scrap plates.

Finally—In 1821 Colonel Paixhan proposed to construct an iron-cased fleet.

In 1835 extensive experiments were conducted at Mentz on plates of forged and rolled iron.

In 1849 experiments were conducted at Portsmouth upon various iron plates with a view to determine their resistance to musketry.

In 1852 proposals were laid before the United States Government for constructing floating batteries of iron so thick that they could resist shot and shell.

In 1853 the proposal to cover ships with an armour casing was reproduced by Napoleon III.

In 1858 our first experiments against thick plates took place at Portsmouth against H. M. S. Alfred, of 50 guns, covered with 4 inch plates, and further experiments have been duly carried on.

He did not for a moment pretend to have treated this important subject in the scientific manner it deserved, but had given his humble assistance to further, though in a slight degree, the development of knowledge on a subject so important, and should he thus awaken a discussion and further

investigation of the subject by those who were more able, he should rejoice that his humble endeavours had not altogether been in vain.

DISCUSSION.

Mr. F. Young would be glad to hear the merits of inclined, as well as vertical sides to our war-ships discussed. He was of opinion that inclined sides would be found superior to vertical. He could not agree with the reader in regard to the Armstrong gun; the details of which he considered were open to serious objections.

Mr. J. T. Kershaw considered the money spent on such ships as the Warrior, would have been much better employed in the construction of small gun-boats, steel-plated at the bows; he contending, that ships of the latter class were much better adapted for the defence of our coasts, and that they could, when armed with an Armstrong or Whitworth gun, successfully baffle their larger antagonists. He considered that the money required to build one such ship as the Warrior would suffice to build many gun-boats, and that the loss of one gun-boat would be comparatively of little importance, whereas the loss of a Warrior in a battle would be fatal.

Mr. Louch described the armour plated batteries constructed during the Crimean war, the chief defect in which was, that through some mistake in the calculation for displacement, the ports were brought within a few inches of the line of flotation, and the vessels would therefore be almost useless in rough weather.

Mr. Waller would be glad to know the most approved method for fastening the plates, whether bolts or rivets were used, and the distance they were placed apart, and also the plan adopted for joining the plates together.

Mr. J. Glynn, Jun., could not agree with Mr. Kershaw, that the gun-boats could successfully contend against such ships as the Warrior; but that, from the great speed of these new plated war ships, they would be able to run them down, while they themselves would be secure from the shot from the guns of the small boats, in consequence of their plated sides.

He thought the reader was in error when he quoted Mr. Fairbairn as having stated that armour plates "could" not be made of English iron, he understood Mr Fairbairn to say, that they "were" not so made.

Mr. T. W. Rumble, in reply to the various points raised in the discussion, stated, that he had only laid before the Society such information as he was able about the Armstrong gun, and was not aware that he had praised it. With regard to armour plates, he thought steel was applicable, if made of an homogeneous metal. He thought hammered plates were not the best that could be used for armour plates, and believed that plates made on the Bessemer, or other similar plan, which melted the parts and produced a perfectly homogeneous mass, would prove to be most adapted for the purpose. The plates, he considered, should be rather soft than otherwise, thus requiring a peculiar mixing of iron.

The question of fastening the plates to the sides of the ships was a very important one. In the Warrior and Black Prince the plates were drilled and bolted to the sides, the bolts being about 18″ apart.

He thought there was little fear of the small gun-boats being able to do much injury to such ships as the Warrior, which was so much superior in speed and armament.

November 4th, 1861.

E. RILEY IN THE CHAIR.

ON SURFACE CONDENSERS.

By JOHN LOUCH.

The author commenced by describing the different methods formerly used to effect the condensation of steam in the steam-engine, commencing with Savery's arrangement shown in diagram No. 1, which consists of two vessels A A′, connected with a steam-boiler by the pipes S S′, and with the well or reservoir from which the water has to be raised by the suction pipes B B′, also by means of the same branch with the delivery pipe C C′. The steam from the boiler is made to pass by the pipe S into the vessel A. When the vessel A is full of steam, the communication with the boiler is closed, and the cock W, which is connected with the cistern of water above, is opened, and a stream of cold water is allowed to fall over the exterior surface of the vessel A. The reduction of temperature thus effected con-

denses the steam within the vessel A, and a vacuum is formed therein, into which the water flows by atmospheric pressure through the suction-valve B, the steam is then again admitted into the vessel A, and by its pressure forces the water through the valve C, into the discharge pipe to a height in proportion to the force of the steam in theboiler. These operations are carried on alternately with the vessels A and A′.

In Newcomen's engines, represented in diagram 2, the steam is admitted from the boiler A into the cylinder C, through the cock B, which, when the air has been expelled, and the cylinder filled with steam, is closed. Cold water is then admitted by the cock D from the cistern E, and, filling the casing F around the cylinder, condenses the steam therein, and thereby produces a vacuum. The atmospheric pressure now comes into operation and depresses the piston, which, by its connection with the overhead beam at the inner end, raises the other end, which is attached to and works the pump. The cock D is now closed, and G opened, to allow the condensing water to flow off into the cistern H. The cock B is again opened, and the steam admitted into the cylinder, by which the air and condensation water are expelled through the snifting pipe I; and the counterweight K, now preponderating, raises the piston to the top of the cylinder, and another stroke commences, as before described.

In working one of these engines it was observed on one occasion to make several strokes in quick succession; and, on searching for the cause, a hole was found in the piston, which admitted the water (which was supplied to the top for the purpose of keeping the packing air-tight) to the cylinder. Taking advantage of this accidental discovery, they were afterwards invariably made with a jet of water injected into the cylinder, instead of merely to its external surface as before; and condensation by surfaces of cold metal was for some time abandoned.

About the year 1764, the celebrated James Watt, having occasion to repair a model of Newcomen's engine, belonging to the University of Glasgow, discovered that there was a great loss of steam by condensation caused by the cooling of the cylinder by the injection water. The idea then suggested itself to him to use a separate vessel in which to effect the condensation. The idea was carried out in the following manner, quoting his own words:—(see diagram No. 3.)

"I took a large brass syringe 1¾ in. diameter and 10 in. long, made a

cover and bottom to it of tin plate, with a pipe to convey the steam to both ends of the cylinder from the boiler, another pipe to convey steam from the upper end to the condenser (for, to save apparatus, I inverted the cylinder).

"I drilled a hole longitudinally through the axis of the stem of the piston, and fixed a valve at its lower end to permit the water, which was produced by the condensed steam on first filling the cylinder, to issue.

"The condenser on this occasion consisted of two pipes of thin tin plate, 10 in. or 12 in. long, and about one-sixth of an inch diameter, standing perpendicularly, and communicating at top with a short horizontal pipe of large diameter, having an aperture on its upper side which was shut by a valve opening upwards. These pipes were joined at bottom to another perpendicular pipe of about an inch diameter, which served for the air and water pump, and both the condensing pipes and the air pump were placed in a small cistern filled with cold water."

Although Mr. Watt abandoned the plan of surface condensation, and adhered to the injection system, he still occasionally turned his attention to it; and about the year 1776 he submitted to Parliament a plan of a surface condenser, consisting of a number of small tubes. This, however, he abandoned, finding, it is said, that he could not obtain by that means so sudden or so perfect a vacuum as by injection, and, also, that the tubes became furred by a deposit which impeded the process of condensation.

He also, at a later date, included, in his patent of a road locomotive, a system of surface condensation, the air, on the external surface of the tubes, carrying off the heat: but I am not aware that he ever carried this plan into execution.

In 1797, Mr. Cartwright designed and patented the engine shown in diagram 4, where the exhaust steam from the cylinder passes into an annular copper vessel S, surrounded on both sides with water W. The condensation water, together with any air which may have entered through imperfect joints, is withdrawn by the pump P, worked by a continuation of the piston rod, and is thus returned to the boiler by the discharge pipe F, through the cistern G, in which there is an ingenious apparatus for getting rid of the air. This scheme failed, partly through want of sufficient condensing surface, and partly from the general bad design of the engine.

In 1821, a surface condenser was fitted by Mr. Napier to a vessel called the Post Boy; it consisted of a number of tubes of copper, $\frac{5}{8}$ in. diameter, and 12 ft. long, but, being constructed only for experiment, it remained in use only for a short time.

We hear but little more of surface condensation until about 1830 to 1835, when Mr. Hall, of Nottingham, again brought the subject before the public, and very sucessfully applied it to the engines of several steam-vessels.

Diagram 5 is an elevation of the engines of the Hercules, in which it will be seen that the steam from the cylinder enters the upper chamber A of the condenser, which communicates with the lower chamber F by the tubes B contained in the cistern C. These tubes are surrounded by cold water, which enters the cistern by the opening D, and flows off at the opening E. G is the air-pump, by which the water formed by the condensation of the steam in its passage through the tubes, together with any air or uncondensed steam which may be present is drawn off from the condenser, and conveyed through the feed pipe H to the boiler.

In order to effect an equal distribution of the steam amongst the pipes, a perforated plate K is fixed in the upper chamber A, a short distance above the tubes.

Having briefly traced the history of surface condensation the author proceeded to enumerate the advantages it possesses as compared with the injection system, especially with reference to the marine steam-engine.

In the ordinary injection condensers the steam is necessarily mixed with the condensing water, and, consequently, whatever impurities this water contains are continually, by means of a feed-pump, forced into the boilers. In ocean steamers this circumstance is of serious importance, inasmuch as sea water contains in solution as much as 3 per cent. by weight of common salt, a proportion which, large as it is, becomes rapidly increased or concentrated by constant evaporation. Sea water also contains small quantities of salts of lime and magnesia, and occasionally other impurities, all of which combining with the salt are deposited on the surfaces of the flues or tubes, and soon form thereon a thick crust or scale, which, when once firmly attached, is with great difficulty removed. Much of the salt and other freely soluble matter is, however, got rid of by the process of "blowing off." By this process when the water in the boiler is found to have reached a

certain degree of density, which is ascertained by means of an instrument called a salinometer, a considerable portion of it is blown out, and, this being in a boiling state all the heat imparted to it is wasted.

This process is repeated generally at intervals of about two hours, and in this manner from one-third to as much as two-thirds of the water supplied to and heated in the boiler is blown to waste. In this manner from 10 to 30 per cent. of fuel is, in reality, thrown away. Notwithstanding that this process is constantly carried on, a scale or deposit forms more or less quickly, in proportion to the temperature of the water, or, in other words, the pressure of steam in the boiler. This has to be chipped off at a great expense of time and labour, and not unfrequently injury to the boiler. If the removal of the scale is neglected, its pernicious effects are soon perceived; for, in the first place, being a bad conductor, it impedes the passage of the heat from the fuel to the water, and causes thereby a wasteful expenditure of fuel, and the plates of the boiler become heated to an extent rendering collapse of the crown plates of the furnace a by no means uncommon occurrence.

Now, in surface condensers, the exhaust steam is not allowed to mix with the condensing water; hence the product of condensation in the form of pure water is alone returned to the boiler; consequently the evils of the injection system above detailed are obviated. It has been found in practice that boilers used with surface condensers will last about three times as long as those where injection condensers are used; and the boilers are not liable to be injured or destroyed by the water becoming too low, for as every cubic foot of water converted into steam in the boiler is, by condensation, re-converted into the same quantity, and returned in its integrity to the boiler—the bulk, and consequently the height, is maintained the same, with the exception of a trifling amount of loss by leakage, &c.

The boilers may also be made of a much smaller size, as no allowance is needed for blowing off, and, as no deposit can take place, or scale form, the conducting power of the plates or tubes would remain unimpaired, and, consequently, would admit of their heating surface being considerably reduced. The air pump, which serves also as feed pump, is much smaller, as it has no injection water to remove from the condenser against a vacuum, and but very little air, viz., that which may accidentally leak through defective joints, or imperfect stuffing-boxes, and not, as in the injection condensers, all that may pass with the injection water, which,

in stormy weather, at sea is very considerable in amount; hence, surface condensers generally indicate a greater amount of vacuum. Again no silt or sand is carried with the steam into the cylinder or air pump, which, under the injection system, are much injured from that cause.

The greater source of economy will, however, be realised by the facility with which a much higher temperature of steam may be used under the system of surface condensation as compared with that of injection. Many attempts have been made within the last few years to increase the pressure of steam in marine boilers beyond the usual 15 lb. to 30 lb. per square inch, and to use it more expansively, but without success, except in those cases where surface condensers have been used; as, at high temperatures, the scale and salts accumulate so rapidly, that the boilers require almost constantly blowing off. The economy to be obtained by the use of high-pressure steam and high degrees of expansion is so well known, that he need dwell no longer on this subject, simply remarking that Messrs. Williamson and Perkins have succeeded (with the assistance of a surface condenser) in using steam at a pressure of 500 lb. per inch, and a very high grade of expansion, at a cost of only 1¼ lb. of coal per horse power per hour.

Most of the advantages resulting from the adoption of surface condensers in the marine engine may be obtained, though, perhaps, to a less extent in stationary engines, and possibly, even in locomotives. Ordinarily, the boilers have, in consequence of a deposit or sludge, to be periodically blown off, and the imperfectly soluble salts which are present, more or less in all spring water, form a scale nearly as quickly, and as hard and difficult to remove as in the marine boilers, as shown by specimens handed round. The first from a boiler using water from a well in the London Docks, and was formed in six weeks, and is, in some parts, ½in. in thickness. The other is from a locomotive boiler from the Great Western Railway, formed in a fortnight. The water, in some parts, contains also highly corrosive ingredients, which destroy the metal, as shown by a specimen of a boiler plate fron the Dowlais Ironworks. This plate was originally ⅝in. thick, and is, after two or three years' use, in some parts completely perforated, and in no part does the metal exceed ⅜in. thickness; the corrosive matter, in this case, was a salt of iron.

Surface condensation may also be applied with great advantage to

existing high-pressure or non-condensing engines, in which there is, in most instances, a back pressure arising from the escaping steam, amounting to about 3 lb. per square inch, instead of which the surface condenser would substitute a positive pressure of from 13 to 14 lb.

On the other hand, the following objections have been urged against the system :—

Their great cost. The cost of the various plans of condensers is from £5 to £10 per nominal horse power; this, however, is the cost when they are substituted for injection condensers, but in the construction of new engines on this system, from this amount must be deducted the cost of the injection condensers and air pump, which would be required on the jet plan; when, moreover, we consider that in surface condensation the boilers may be reduced to nearly half the usual size, and other parts of the engine in proportion to the extra pressure of the steam obtained, the balance would be in favour of the surface system.

That the condensation does not take place with sufficient rapidity. This opinion, being only based on theoretical reasoning, does not exist to any appreciable extent in practice when a sufficient area of surface is provided, excepting, when, through want of a little attention and cleaning, a scale is allowed to accumulate, which has been, undoubtedly, the cause of their abandonment in many cases.

The liability of the tubes to split or crack and admit air to the condenser. This has been provided against by the adoption of several different plans, presently described.

The liability of the tubes to corrode and fur up. To this defect they are, no doubt, more or less liable, according to the nature of the water employed for condensation; but, as that water is always at a comparatively low temperature, and the tubes being of a material less liable to corrosion than that of which the boiler is formed, will be compensated for, perhaps tenfold, by their saving the boiler. Surface condensers in ocean steamers have been at constant work for three years, and at the end of that time were in a state which, practically considered, was as good as when new.

Their weight and bulk, which is however, so little in excess of the injection condenser, that it is scarcely worth considering as an objection.

Having referred to the principal points for and against the system of surface condensation, the author proceeded, with the aid of the diagrams,

to describe the various plans which have been proposed to carry out the system.

Hall's plan, already described, is represented on diagram 5. In the first condensers made on this plan, the tubes were fixed by having a collar screwed up to each side of the tube plate, which did not allow of the unequal expansion of the tubes, which, consequently, split or cracked, thus giving access of air to the condenser. He, therefore, adopted the plan of fixing securely one end of the tube to the tube-plate, allowing the other end to work freely through a stuffing-box, as represented in diagram 7.

In order to supply the place of water lost through leakage Mr. Hall adopted the apparatus shown on diagram 6. To regulate the supply of distilled water, so as to maintain the water in the boiler at a proper height, a cock C is placed between the pipe B and the distilling vessel A; by opening the cock C, the steam from the distilling vessel is allowed to pass into the condenser, where it is condensed and passed, with the condensation water, into the boiler. When the proper level in the boiler is attained the cock C may be closed. The distilling vessel is connected with the cold water cistern by the supply pipe D, to which is fitted the cock E, and the water is maintained at a proper height in the distilling vessel during the distillation by means of the float F and valve G. Any sediment may be blown off from the distilling vessel through the pipe H, fitted with the cock K, by the pressure of the steam admitted through the pipe I and cock M; thus, by shutting the cocks C and E, and opening K and M, the pressure of steam from the boiler, acting on the surface of the water in the distilling vessel, drives it out with its impurities through the pipe H. The distilling vessel is let into the boiler, the steam in which supplies the required heat. Several plans have been used to effect this purpose, all acting more or less on this principle.

The left-hand figure on the same diagram represents Mr. Hall's "Steam Saver," its office being to cause the steam which usually escapes at the safety valve to enter the condenser, so that the distilled water resulting from its condensation may be restored to the boiler by the action of the air-pump, or any other suitable means. *a*, *a*, is a cylindrical vessel closed at top, and the lower end plunged in mercury contained in a circular groove or cavity formed between two concentric cylinders *b b*. These cylinders are supported upon a square box which is closed at bottom and communicates with the

boiler by the opening *c*, and with the condenser by the bent pipe *d*, to which latter is fitted a sliding valve *e*, having a small aperture over which slides a valve *f*. The cylinder *a* is loaded by the weight *g g* suspended within it, to which is attached the frame *h h ;* the stem of the valve *f*, is attached to this frame, and the stem of the valve *e* works freely in a hole in the frame, and has a nut at the upper end, at a short distance above the lower bar of the frame.

Mr. David Napier devised a plan which will be understood by referring to diagram 8. It consists of a number of horizontal tubes, in a wooden box open to the sea, and passing through a stuffing-box in the tube plate similar to that described, as used by Hall, and at the other end forced through a ring of India-rubber, previously inserted in a recess in the tube-plate, as shown in diagram 7, openings through the vessel's side for supplying the condensing water were provided with flanges so arranged that whichever way the vessel was moving a current of water was constantly flowing through the condenser. In this, which is a very simple and economical arrangement, the flow of condensing water would be hardly sufficient.

The plan adopted by Mr. Sewell, of New York, and introduced into this country by Mr. Davison, will be understood by referring to diagram 8. It consists of a number of tubes placed horizontally, passing freely through holes in each tube plate, and, projecting a short distance at each end. Over their ends, is passed a sheet of India-rubber, punched with holes corresponding with the holes in the tube-plate, and through the tubes are forced, thus forming an hydraulic cup-joint. The India-rubber is kept to the tube-plates by a gland, as shown in the diagram 7, which also serves to keep the tubes in place. The water is forced by means of a circulating pump through the tubes in the direction of the arrows W, diagram 8, and steam is admitted through the branch S, the condensation water being drawn off through the branch C. In this condenser the tubes are very easily withdrawn for cleaning or renewal, and it is a cheap and efficient condenser.

Mr. Spencer's condenser, which has been somewhat extensively used, and with good results, is similar to Sewell's, with the exception of the packing which is shown in diagram 7, consisting of one or more India-rubber rings passed over the ends of the tubes and driven firmly into recesses provided in the tube-plate.

The expansion of the tubes has been provided for in many other ways by different inventors. The plan recommended by De Bergue, represented in diagram 7, consists of two tube-plates, with a sheet of India-rubber between them, with holes corresponding with the holes in the tube-plates. When the tubes are in their places the two plates are screwed together, thus expanding the India-rubber laterally and making a firm and tight joint.

Another plan (also represented in diagram 7), proposed, and, I believe, adopted with success, by Mr. Turner, consists of melting into a recess around the tube tin or other soft metal, which is afterwards caulked. It forms a tight joint, allowing the tube to expand, and can, if necessary, be very easily recaulked.

The expansion of tubes is provided for in the patent of Messrs. Howden and Morton by bending the tubes in the form of the letter U, both ends being fixed in the same tube-plate, as shown in the diagram 9. The water circulates through the tubes, the steam being on the outside. It would, no doubt, form a very good condenser, but the tubes would be very difficult to clean.

Another plan for effecting the same purpose has been patented by Mr. Miller, of Washington, shown diagram 9, consisting of a tube of comparatively large diameter, with a conical tube, fixed to the inside, the smaller end being closed, and extending nearly to the mouth of the outer tube.

Mr. Miller states that he has found by experiment that water at a comparatively high temperature is more efficient in the condenser than cold water. This is, however, quite contrary to the experience of the author.

Diagram 10 represents a condenser patented by Messrs. Williamson and Perkins. The exhaust steam from the boiler is admitted by the branch S into a cast iron box, containing a number of tubes A closed at their upper ends, and firmly fixed into a tube-plate at the lower end, being allowed to expand and contract through the holes in the upper plate, which serves to keep the tubes in place. Inside these tubes are others of smaller diameter, B, open at both ends, the lowel ends being firmly fixed in the diaphragm of the chamber D, and reaching nearly to the closed ends of the tubes A. Water is admitted by the branch W through the chamber D into the tubes B, and, passing through their upper ends, returns through the

annular space between the two tubes, thus cooling the outer tubes and condensing the steam, the condensation water from which is removed by the air pump through the branch C, and is returned to the boiler.

By an arrangement not shown in the diagram (should any leakage take place) a valve attached to the inlet branch W being partially closed, the circulating pump attached to the outlet branch W′ acts under such circumstances as an air pump, and causes a partial vacuum on both sides of the tubes, thus preventing the access of condensing water to the condenser. This condenser has been used with considerable success by Dr. Williamson, and possesses many advantages over the ordinary condensers; firstly, by the condensation water having all to pass through the annular space between the tubes must necessarily (the same quantity being used) pass much more rapidly over the surfaces than when the water fills the whole of the tubes, and thus present a large surface of water, and at the same time, by its rapid motion, diminish the quantity of scale or sediment on the tubes. The tubes are also free to expand and contract unequally by being fixed at one end only. On the other hand, it would be very inaccessible for cleaning, and, from the double number of tubes, expensive.

The next figure represents a plan patented by Messrs. Randolph and Elder, and consists of a number of alternately right and left spiral tubes, attached at one end to the top pipe W, the other end fastened to the lower branch W, and enclosed in a cast iron case, into which the exhaust steam is admitted through the branch S, and the condensation water withdrawn through the branch C, the condensing water being made to pass through the spiral tubes.

This condenser would, undoubtedly, expose a large condensing surface, and would not be affected by any unequal expansion and contraction of the tubes, but it would be expensive and difficult to manufacture, and inaccessible for cleaning.

Diagram 12 shows a plan adopted by Du Tremblay for allowing for the expansion and contraction of the tubes by forming a chamber on the tube-plate, the upper end of which works in a stuffing-box in the condenser case, thus allowing the tubes to expand equally. But as the expansion is very unequal (those tubes nearest the steam inlet expanding to a much greater degree than those at the opposite side of the condenser) this plan was not found to be of much value. In the condensers made by Du

Tremblay the tubes were of an elliptical form, and being fixed in the mould, the metal for the tube-plate was cast around them, which made a very effectual joint. But the tubes could not be removed for renewal.

On the same diagram is represented a plan for obtaining cooling surfaces, patented by Mr. Davison, of London, consisting of two sheets of corrugated metal, rivetted or otherwise fastened together. By this plan a large and effective cooling surface is obtained at a moderate cost.

The next figure will serve to illustrate a plan adopted with great success by Mr. Rowan, of Glasgow. It consists of a number of tubes, contained in a case, and surrounded with water, which is kept in motion by a fan or agitator. To this agitator is due the superiority of this over former condensers.

The exhaust steam from the engine enters at the top, passing through a lantern-shaped frame covered with wire gauze, placed on the end of the steam pipe. The steam passing through the tubes is condensed, and the condensation water withdrawn by the air-pump. The tubes pass through stuffing-boxes, as shown in fig. 7 diagram 7. The packing used is a short length of India-rubber tube lined with linen, to allow the tube to pass easily through without sticking. On these tubes are placed ferrules, pressed down to their places by plates, perforated to correspond to the tubes, which they also serve to keep in their places. Six or eight of these plates only are used to all the tubes in the condenser.

The condenser, although necessarily somewhat more complicated than the plans above described, appears to possess advantages over them, the surface being considerably reduced. It does not appear to be very accessible for cleaning or repairs.

In the condensers hitherto described the condensation is effected by the circulation of a body of water, but other plans have been proposed, and, to some extent, used, in which the process is effected by the evaporation of the condensing water which is sprinkled upon instead of surrounding the tubes in a solid body, On this plan several have been made by Mr. Pirsson, of New York, as represented diagram 14.

The tubes through which the steam passes are fixed into thin copper tube plates, and water allowed to fall or trickle over them from a perforated pipe or rose. The waste water and air are withdrawn by the lower branch W. In these condensers a communication is made between the exterior and interior of the tubes by means of the orifices B.

By this contrivance the pressure is equalised and all strain on the tubes and plates removed, but the arrangement involves the loss of upwards of 25 per cent. of the condensation water. These condensers, at least in some cases, wear out quickly, those placed on board the State of Georgia, an American vessel, having been renewed three times in six years. This system has the following advantage, that should the condenser get out of order, by removing the tubes, it is converted into an injection condenser.

Condensers of this class have the advantage of being lighter than those before described, owing to their not having so great a body of water in them.

Messrs. Pontifex make condensers, as shown in diagram 15. Copper tubes of large diameter are fixed at each end into a cast iron box, allowance being made at one end for expansion by a collar of India-rubber attached to the tube, and also to the socket, as shown. The condensing water is made to fall on them in the form of shower, and is rapidly evaporated by the steam within, which is thus condensed. Many of these condensers are in use in London producing good results, but they are only adapted for land engines and to be fixed to the exterior of the engine-house; they are also subject to rapid corrosion.

Mr. Perkins has a very successful condenser represented in diagram 16. It is composed of a number of horizontal iron tubes of small diameter, screwed into vertical tubes of 3 in. diameter, $\frac{3}{8}$ in. thick connected with the exhaust steam pipe on the one side, and the condensation water pipe on the other. The small horizontal pipes are, after being screwed into the 3 in. pipes, caulked up, thus making a secure joint, and, from their length and small diameter, bend when unequal expansion takes place. The steam passes through the tubes, the condensing water falling on the exterior surface. This condenser produces good results.

Mr. Perkins proposes, in some instances, to enclose this condenser in a case, and from thence form a communication with the furnace or chimney of the boiler, which, by the rapid current of air passing through, would, no doubt, increase its efficiency.

Mr. Howden also has patented a condenser based on this principle.

On this principle, also, as long ago as 1822, previous to the experiments of Mr. Hall, Mr. Clark patented a very ingenious though somewhat complicated condenser, represented in diagram 17. The steam is condensed in

small tubes fixed into larger ones which radiate from a centre, over which water, in the form of a shower, is made to fall; the rapidity of the condensing water is accelerated by means of a fan placed in the centre. It would, no doubt, be very efficient, although subject to the same rapid deterioration from oxidation as others made on this principle.

Diagram 18 represents a condenser patented by Messrs. Samuel and Nicholson, applicable to paddle-wheel engines. The steam in this example is admitted through a perforated pipe into a case provided with a number of tubes, the outer surface of which is kept wet by the water thrown up by the paddle-floats, thus dispensing with circulating pumps. As a condenser its position would be exceedingly objectionable.

The two concluding figures represent a plan of the author's, in which he had endeavoured to remedy, as far as possible, the defects pointed out in some of the examples before referred to. It consists of a case containing a number of tubes, through which the condensing water is made to flow in a circular film instead of their being wholly filled, as is the usual practice; or, on the other hand, simply sprinkled with water. This film is caused by inserting in the upper end of the condensing tubes short pieces of tube slightly smaller in diameter, thus leaving an annular space between the two, through which the water flows in the form of a hollow column. These interior or distributing tubes may be corrugated in a spiral direction in order to give to the water a motion in a spiral direction, and thus compel it to maintain the form of a film under all circumstances throughout its entire course. A current of air, produced by mechanical means, or by forming a communication through the opening A with the boiler furnace or chimney, is made to pass through the centre of the tubes, and thus materially increase the rapidity of action of the condenser.

It possesses this advantage over those condensers in which condensation is effected by the evaporation solely, that, by the tubes being constantly covered with a current of water, very little, if any scale, can form on their surfaces, and the tubes are not so subject to corrosion as when they are exposed to wind and water. Compared with the other description of condenser where water is allowed to flow through in a body, it is more rapid in its action, thereby rendering a less amount of condensing surface necessary.

This has been proved by experiments as follows:—Using a model

with the tubes filled with water, which, after passing through the tubes, ran over the outside, thus making the surface of the case available in addition to the tubes, steam was admitted from a boiler, at about 16 lb. pressure, to such an extent as just to cause steam to issue from the branch through which condensation water alone should issue, thus proving that the condenser had as much work as it could do. The circulating water passed off at nearly 200 deg. Then altering the condenser to the plan above described and using the same quantity of condensing water (none of which, however, was allowed to pass over the outer case, as in the first instance), it was found to condense a greater amount of steam, and the circulating water passed off at a much lower temperature, viz., 110 deg. A further advantage is, that the tubes can be cleaned or have their packing tightened, or, if accidentally split or otherwise damaged, they may be plugged up at any time, even whilst the engine is at work. This will be understood by reference to the concluding figure.

The screwed tube, which passes through the upper plate or cover, gives the necessary pressure to the packing, and is at all times accessible for readjustment; it also forms a socket for the distributing tube, on removing which the condenser tube may be cleaned with a brush, or in any other way. In no other form of enclosed tubular condenser can the tubes be cleaned or the packing adjusted whilst the engine is in motion, or without removing some portion of the case.

This of course, requires time and labour, and causes delay. This difficulty has been the cause of many condensers having been neglected, and consequently abandoned, and the injection system substituted.

There is another class of surface condenser, in which the heat is carried off by the air alone. An early example of this kind of condenser has already been alluded to in the first part of this paper as having been included by James Watt in his patent for a road locomotive.

Mr. Craddock has patented a condenser on this principle, and applied it with some success. He causes the whole condenser, consisting of a number of small tubes, to revolve rapidly, thus causing a constant change of air to the tubes. This is necessarily an expensive and complicated arrangement, and has not come into extensive use.

Mr. Perkins has also patented an air condenser, consisting of a large number of vertical tubes of small diameter, partially open at the top, the steam

being admitted at the bottom. These tubes he also proposes to enclose in a case, and form a communication with the furnace or chimney of the boiler. In this condenser no vacuum is formed, it being designed only to return the pure water to the boiler. He has used a condenser on this principle with some success, but has abandoned it in favour of his plan already described.

Air condensers have not come into use in consequence of their slowness of action, especially in warm weather.

There is another system of condenser which, although not strictly coming under the head of surface condensers, possesses so many of the advantages of that system, that it deserves a brief notice, viz., that of cooling the injection water of an ordinary condenser to be used again for the same purpose, thus allowing fresh water only in the condenser, and consequently in the boiler. This has generally been effected by passing the water through tubes contained in cases open to the sea or otherwise cooled. He thought it was first proposed by Symington, and it has been since tried by Mr. Sutcliffe, Schiele, Howard, and others, but with indifferent success owing to the water parting so slowly with its heat.

The following are details of a few condensers in actual use:—One by Spencer, applied to a pair of marine engines, cylinders 65 in. diameter, 3 ft. 6 in. stroke, making forty-five revolutions per minute, indicating 1,200-horse power, contains 1,600 tubes 1 in. diameter, 7 ft. 6 in. long, giving about 2½ square feet per horse power, the steam in the boilers being at 25 lb., a supplementary engine and boiler being employed to drive the air pump. These engines formerly worked with an injection condenser consuming 48 tons of fuel a day. This Mr. Spencer, by means of his surface condenser and other improvements, guaranteed to reduce to 30 tons. This he has not quite effected, but it is owing, in a great measure, to defective boilers, which I believe are being replaced.

The cost of his improvements is from £6 to £10 per nominal horse power.

In an example by Rowan, applied to a pair of engines of 200 indicated horse power each, the condenser contained 720 tubes 7ft. long ½in. diameter and $\frac{1}{32}$ in. thick, giving a surface of nearly 1¾ ft. per horse-power, the pressure in the boiler being 100 lb. to 120 lb. per square inch, the vacuum about 25 in. mercury.

Mr. Rowan, however, has constructed condensers with less than 1½ square

feet of surface per horse power, giving a vacuum of 28 in., $28\frac{1}{2}$ in., and even up to 29 in.

A condenser made by Messrs. Merrick and Sons, of Philadelphia, to supply the place of Pirsson's already alluded to as having worn out so rapidly on board the State of Columbia:—The engine is a single side lever, cylinder 72 in. diameter, 8 ft. stroke, making fifteen revolutions per minute; 22 lb. steam in the boiler, worked expansively; indicated horse power, 850 to 900: the condenser contains 2,453 tubes $\frac{5}{8}$ in. inside diameter, $\frac{1}{32}$ in. thick, about 5 ft. 5 in. long; steam on the outside of the tubes. The tubes are firmly fixed into the tube plates, no allowance being made for expansion; amount of vacuum about 25 in. mercury. The condenser occupies a space 5 ft. × 4 ft. × 6 ft. 3 in. high; it has two double-acting circulating pumps 15 in. diameter, 20 in stroke, not quite large enough for their work no tallow or oil used in the cylinder. The loss of water through leakage, &c., is made up by drawing from the sea; and when the boiler is blown off, after 700 miles run, the density of the water is found to be one-fourth that of sea water.

From these and other examples we may draw the following rules:—

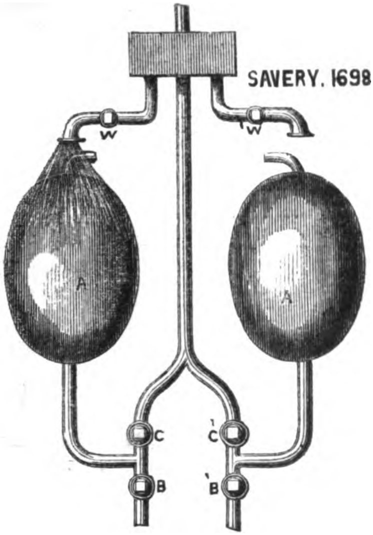
The tube surface generally allowed is $2\frac{1}{2}$ square feet per indicated horse power, though Rowan uses as low as $1\frac{1}{2}$ square feet.

The tubes vary from $\frac{1}{2}$ in. to 1 in. diameter, and from $\frac{1}{32}$ in., to $\frac{1}{16}$ in. thick. Horizontal condensers requiring larger and thicker tubes than vertical, having to support their own weight full of water.

The condensing water is about the same in quantity as for injection condensers.

The air pumps are reduced to from one-half to one-third the capacity.

The average vacuum is higher than in the injection condensers.



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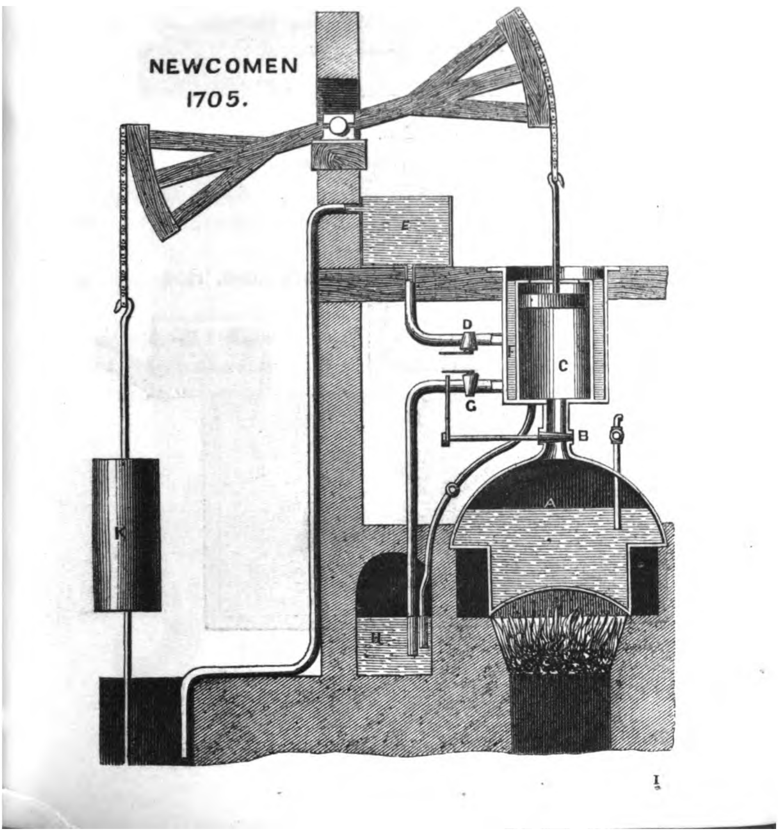

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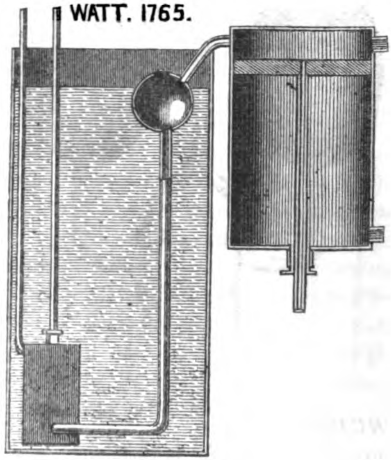

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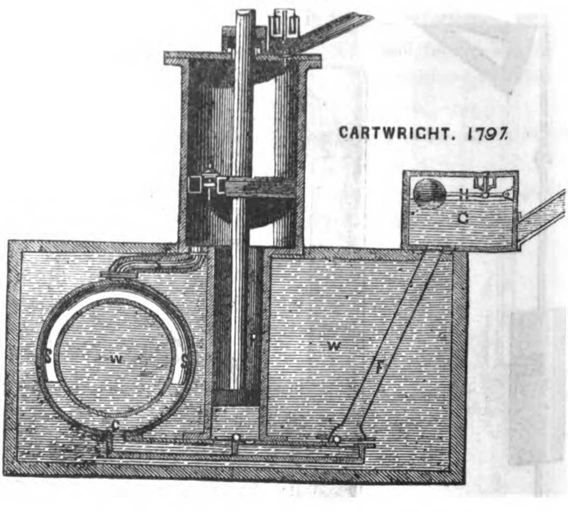

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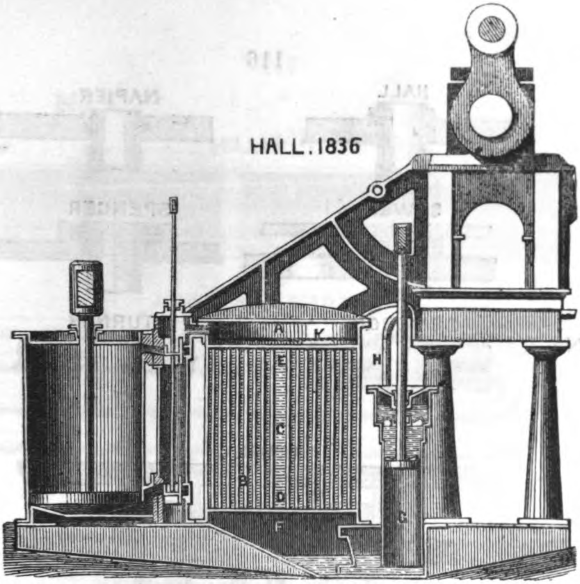

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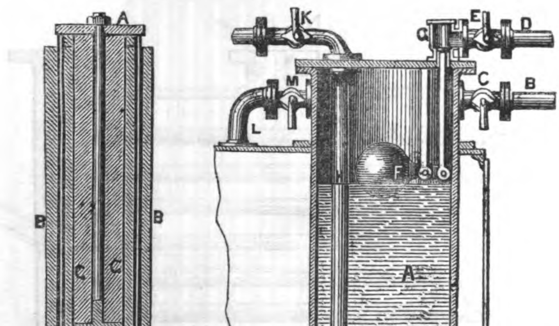

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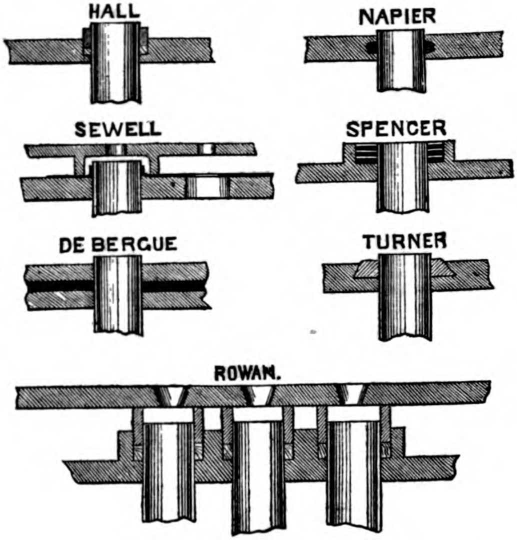

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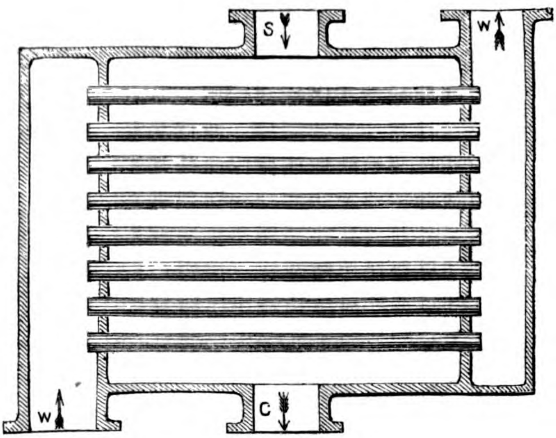

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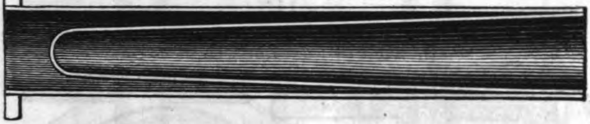

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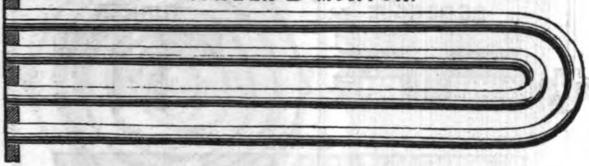

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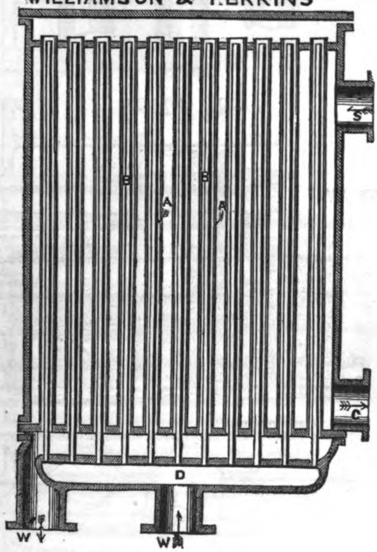

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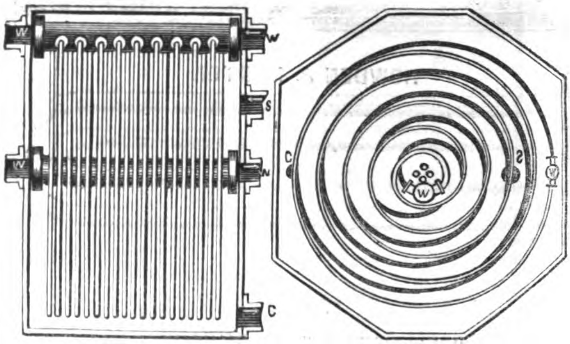
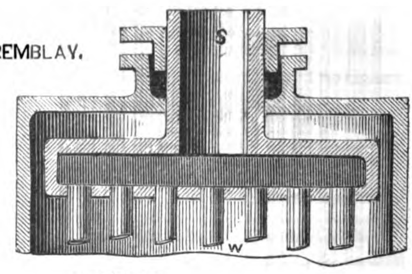
RANDOLFH & ELDER.

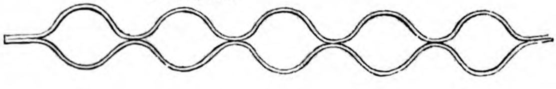


No. 12.

DU TREMBLAY.



DAVISON.



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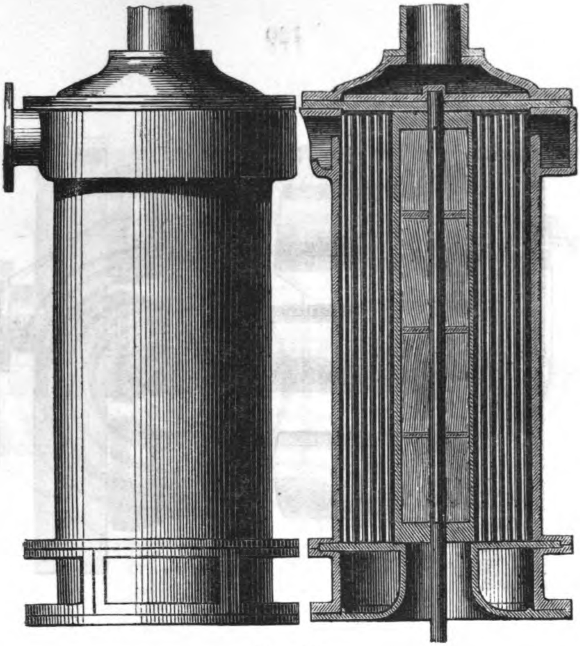

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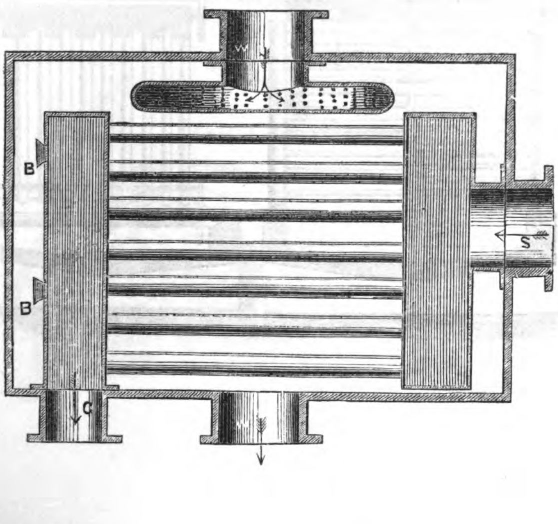
PIRSSON



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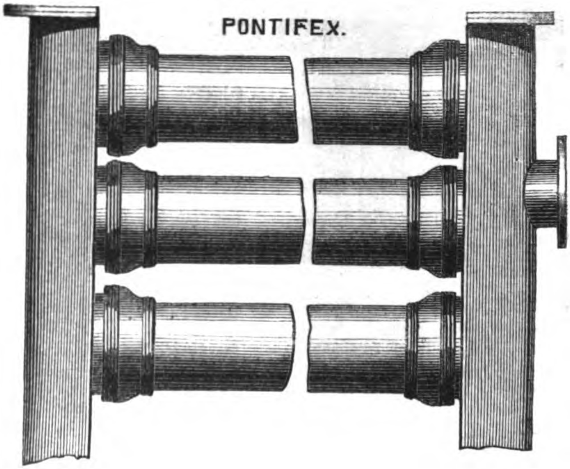

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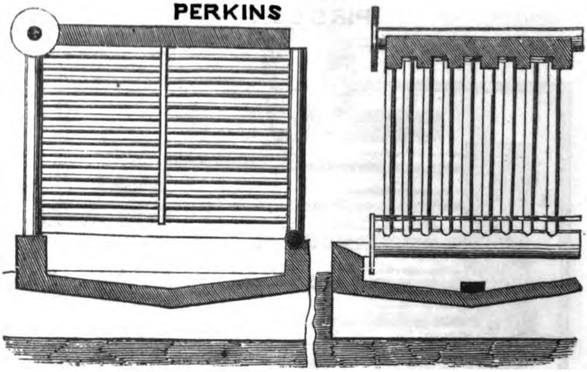
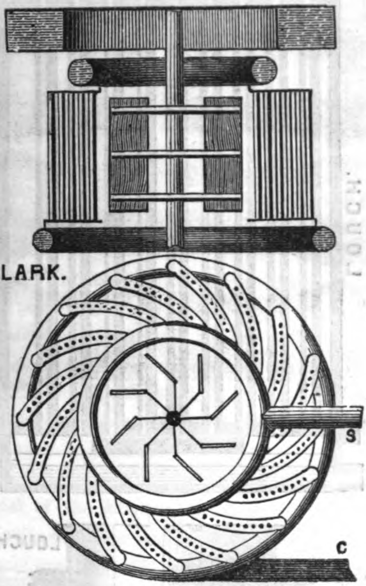


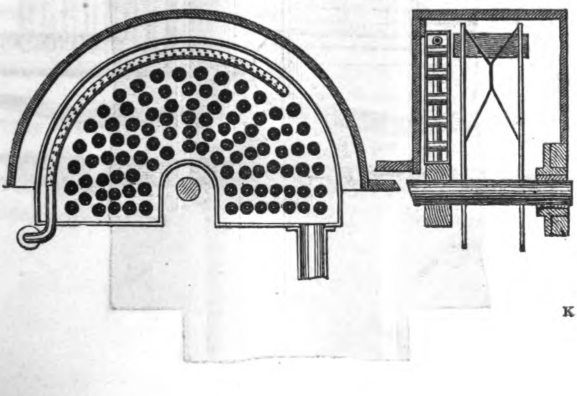
CLARK.

No. 17.



No. 18.

SAMUEL & NICHOLSON.



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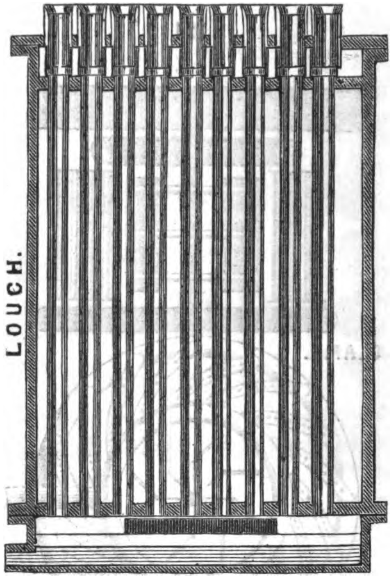
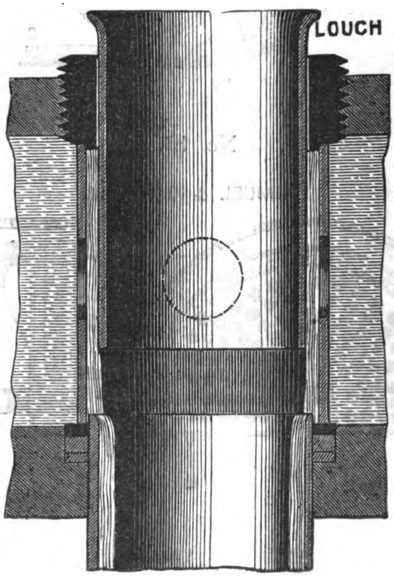


No. 20.



December 2nd, 1861.

J. AMOS IN THE CHAIR.

ON SURFACE CONDENSERS.

By J. LOUCH.

DISCUSSION.

Mr. Louch opened the discussion by reading a few notes on the trials of steam-vessels Octavia and Moultan, which had taken place since the ding of his paper. The former built for the Navy, with engines by ssrs. Maudsley and Field was fitted with a surface condenser, containing rly 11 miles of metal tubes placed vertically. The boilers also were ed with superheating apparatus; the boilers being only two-thirds the e of those of the same power in other vessels of the Royal Navy. On her al she consumed only one-half the quantity of fuel ordinarily consumed by gines of the same power. The pressure of steam in the boilers was 20 lb. square inch, vacuum in condensers 28½ inches, and her mean speed ½ knots.

On the first trial of the Moultan, belonging to the Peninsular and iental Steam Navigation Company, the engines by Humphreys and nnant, she had only consumed 630 tons of coal against 1200 tons under linary circumstances by other vessels of the same power, being at the rate 2 lbs. of fuel per horse power per hour.

He also gave the results of some experiments made by Mr. Joull, as ven by him in a paper read before the Royal Society, as follows:—

"That the pressure in the vacuous portion of the condenser is the same in parts."

This, Mr. Louch said, was not found to be the case in practice, as a slight ference existed between the pressure in the upper and lower ends of the ndensers.

"That it is a matter of indifference whether the water flowed in the me or the contrary direction to the steam."

"That water was found to be much more rapid in its action as a ndensing medium than air."

With the two latter remarks Mr. Louch entirely concurred.

Mr. Young described a condenser, invented by Mr. Craddock, in which air was used as the condensing medium, and by which a vacuum of 24 in. was obtained, and which in all respects was successful. Admitting the great improvement and value of surface condensers, he was, nevertheless, of opinion that they would not, under their present form, effect a saving to the extent of 50 per cent, as stated in the instance of the Octavia, but that the most that could be expected would be from 30 to 40 per cent.

The Chairman thought that in many of the systems of surface condensers described, the expansion and contraction of the tubes had been too much considered, he questioned whether the ordinary method of "tubing," as practised in locomotive boilers for instance, would not do equally well, and at much less expense. In fact, in several cases in which he had been concerned, where a modification of the tubular principle, in combination with the ordinary condenser, had been used, such an arrangement had worked well for several years.

He then gave the following practical information, which had come under his immediate observation:—

	Nominal Horse Power.	Cubic Feet of Water.
Steam-ship Jumna	200	250
" Moultan	400	600
" Reiver	5 to 600	600
" Ripon	400	600

were capable of being passed through the condensers by the circulating pumps. This quantity in either case could be doubled, as the circulating apparatus in each case was in duplicate, but, in practice, considerably less than the quantity stated above sufficed. He thought that nothing could be better than a continuous and rapid circulation of cold water, and besides had this advantage, that the bulk of the condenser was materially diminished.

Mr. Louch, in reply, stated, he had heard that good results had been obtained by Mr. Craddock's air-condenser, but he preferred using water, it being more simple and efficient.

With regard to the saving of fuel in the Octavia, he thought, in the usual runs, such a great saving as 50 per cent. would not be effected; but

this vessel had made a run of 6000 miles, and had reduced the fuel consumed nearly to that extent.

With regard to the expansion of the tubes, he did not consider the locomotive boiler, as mentioned by the Chairman, a parallel case, as in locomotive boilers the tubes were gradually expanded, whereas the tubes of surface condensers were suddenly and frequently contracted and expanded, thus producing almost a percussive action; in practice, it had been found necessary to provide for this sudden and unequal expansion.

The Chairman, in summing up, stated, that the subject had been very ably brought before them, and he regretted that more discussion had not resulted from so good and useful a paper.

SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

COMMITTEE AND OFFICERS FOR 1863.

R. M. CHRISTIE, *Chairman.*

G. W. ALLAN, 1857.
H. P. STEPHENSON, 1856 & 1859
R. M. ORDISH, 1860.
J. AMOS, 1861.
E. RILEY, 1862.

Past-Chairmen—Members ex officio.

G. CAMPION.	W. PARSEY.
W. T. CARRINGTON.	E. REYNOLDS.
J. LACEY.	F. YOUNG.

A. WILLIAMS, *Hon. Secretary and Treasurer.*

W. H. LEFEUVRE, *Auditor.*

Place of Meeting, Lower Hall, Exeter Hall, Strand.

JANUARY, 1863.

PREMIUMS

FOR 1862.

At the Meeting of the Society, on January 12th, 1863, Premiums of Books were awarded to:—

Baldwin Latham, for his Paper "On the Inundations of Marshland."

And to

Lewis Olrick, for his Paper "On Marine Governors."

SOCIETY OF ENGINEERS.

RULES AND BYE-LAWS.

Object of Society.

This Society was established for the discussion of scientific and other subjects of general interest.

The Election of Members.

Number of Classes.

1. The Society shall consist of two classes—Members and Associates.

Mode of Election.

2. Members and Associates to be elected by ballot; one third black balls to exclude.

Associates to become Members.

3. Members not to be less than twenty-three years of age. Associates, on attaining that age, may pass to the class of Members on expressing their intention to the Committee, and paying the difference of entrance fee and subscription.

How to be Proposed.

4. Candidates to be proposed by a Member or Associate of the Society and recommended by at least three others, on a proposal form which is to be forwarded to the Secretary at least seven days before any Ordinary Meeting; the ballot to take place at the conclusion of such Meeting.

Expulsion of Members and Associates.

5. No Member or Associate to be expelled without the consent of at least three fourths of the Members and Associates present, or by proxy, at a Special General Meeting, called for such purpose.

Visitors.

6. Members and Associates to have the privilege of issuing cards of invitation for two visitors at each Ordinary Meeting.

Rules for the Election and Proceedings of Committee and Officers.

Mode of Election. **7.** The Officers of the Society to be elected at the General Meeting in December, each year, by ballot.

Number of Officers. **8.** The Officers shall consist of a Committee of seven Members, in addition to the Past Chairmen of Committees, and Honorary Secretary aud Treasurer, who shall be Members ex officio. The Past Chairmen to be limited to six, to retire by seniority, but to be eligible for re-election on the Committee.

Election of Auditor. **9.** A Member (not being one of the Committee) to be elected as Auditor, who shall make his report at the first Ordinary Meeting in each year.

Quorum. **10.** Four Members to be a quorum; the Chairman to have the casting vote.

Election of Chairman.

11. The Committee to elect their Chairman by ballot, who shall be Chairman of all Meetings throughout the year.

Nomination of Deputy-Chairman.

12. In the absence of the Chairman at any Meeting, a Deputy shall be nominated by the Committee.

Management of Funds.

13. The Committee shall have the sole management of the funds, aud the entire superintendence of the Society.

Selection of Subject for Discussion.

14. The Committee shall select the subjects and papers to be read and discussed at the Ordinary Meetings. Members and Associates wishing to read a paper, or who wish to have a particular subject discussed, must notify the same to the Committee.

Special Meeting of Committee.

15. A Special Meeting of the Committee shall be called on the requisition of three of its Members.

ement of nittee. **16.** The Committee to retire each year but to be eligible for re-election.

of New rs. **17.** The Committee resigning office shall prepare a list of proposed new Officers, which shall be sent to each Member and Associate with the notice of the General Meeting.

bers ng to be ted on nittee. **18.** Any Member offering himself for election on the Committee, must give in his name to the Committee on or before the Ordinary Meeting in November. The name of such Member shall be appended to the list proposed by the Committee.

tion of mittee. **19.** Members and Associates who do not attend the General Meeting should forward the abovenamed list to the Honorary Secretary, with such alteration in the names as they desire, which, with those from the Members and Associates present, shall be handed to two scrutineers appointed by the Chairman, who

shall ascertain the number of votes obtained by each Member; and the Chairman shall make known the result to the meeting.

Equality of Votes.

20. In case two or more members have the same number of votes, the election of such Members to be decided by lot.

Rejection of Ballotting Lists.

21. The scrutineers to reject all balloting lists not properly filled up.

Election of Hon. Secretary and Treasurer.

22. The Honorary Secretary and Treasurer to be elected by the Members and Associates of the Society, and to be nominated in the list of Officers proposed by the Committee for the year ensuing.

Custody of Funds and Accounts.

23. The Honorary Secretary and Treasurer shall keep the funds and accounts of the Society, which shall be open for the inspection of any Member or Associate.

SUBSCRIPTIONS, &c.

nce Fee. 24. An entrance fee of twenty-one shillings to be paid by Members and ten shillings and sixpence by Associates on election.

al ription. 25. The annual subscriptions for Members to be twenty-one shillings, and for Associates ten shillings and sixpence, to be paid in advance. They are due on the first day of January in each year.

bers ing ad. 26. Members and Associates residing permanently out of the United Kingdom, shall pay ten shillings and sixpence entrance fee and ten shillings and sixpence annual subscription.

nbers and ociates ing. 27. Any Member or Associate joining the Society shall pay his entrance fee, and first year's subscription, previous to receiving the benefits of the Society, which shall be considered as paid only to the 31st of December ensuing.

Disqualification to Vote.

28. Members and Associates whose subscriptions are unpaid are not qualified to vote.

Subscriptions in arrear.

29. Members or Associates whose subscriptions are in arrear for two years, to be struck off the register of the Society, but to be still liable for the amount due.

Meetings of the Society.

Ordinary Meetings.

30. The Ordinary Meetings shall be held on the second Monday in January, and the first Monday in February, March, April, May, June, September, October, November, and December, unless otherwise specially ordered by the Committee. The Chair to be taken at 7 o'clock p.m.

Special General Meeting.

31. A Special General Meeting of the Society shall be called on the requisition of eight of its Members, who shall send to the Committee the resolutions to be proposed by them at such meeting.

Management of Discussion. **32.** The Chairman to have the power of directing the manner of discussion.

General Meeting. **33.** There shall be a General Meeting held within the first fortnight of December in each year, to elect the Officers of the Society for the ensuing year.

Voting by Proxy. **34.** Members and Associates are entitled to vote by proxy.

Notice of Meetings. **35.** The Honorary Secretary shall write to every Member and Associate at least four days before each Ordinary Meeting, naming the date of the same, the subject of the Paper, and by whom to be read; likewise the names of Candidates for election and by whom proposed.

Order of Business. **36.** The Honorary Secretary shall commence the proceedings of each Meeting by reading the minutes of the one preceding, the abstract of the Paper read, with notes of the discussion

at the previous Meeting, and the names of the gentlemen proposed for election.

Premiums for Papers.

37. Premiums in Books, not exceeding the value of Six Pounds, will be given annually for the best Papers read during the previous year. The decision to be left to the Committee, who are disqualified from receiving premiums.

Publication of Papers.

38. After each Paper is read, the Committee are to decide whether it would be desirable to publish it, and, on obtaining the author's consent, are to arrange with the Editor of a Scientific Journal to publish the whole or part of the same.

Alteration of Rules.

39. No alteration to be made in the above Rules and Bye-Laws without the sanction of a Special Meeting called for that purpose.

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Elected.	
1858	C. D. Abel
1856	A. Aird
1856	C. Aird
1855	J. Aird
1860	J. P. Adkins
1854	G. W. Allan
1859	J. Allen
1857	J. Amos
1860	G. Anderson
1862	C. J. Appleby
1862	T. H. Appleby
1859	W. J. Arliss
1861	J. Ashby
1862	G. Ashcroft
1859	J. Ashdown
1861	J. Ashlin
1861	J. P. Ashton
1860	E. Aydon
1861	W. B. Backshell
1862	M. Baines
1859	J. D. Baldry
1860	H. T. Balfour
1860	C. Barnard
1860	E. B. Barnard
1861	J. C. Bayley
1860	J. Beardmore
1860	W. Benbow
1854	W. Binns
1862	W. Blackett
1862	G. Bowdler
1862	A. M. Boulton
1861	R. H. Boyce
1859	J. Boys
1862	D. H. Brandon
1858	R. Brass
1862	E. Bray
1861	J. Brenchly
1859	E. W. Briscoe
1860	R. Broad
1854	G. Broaderick
1856	Lieut. Broaderick, R.N.
1859	J. B. Brown
1861	W. H. Browne
1862	A. B. Brown
1858	A. G. Browning
1857	C. E. Browning
1859	F. W. Bryant
1856	C. Burn
1854	D. Campbell
1860	G. Campion
1859	J. Carrick
1858	W. T. Carrington
1854	R. M. Christie
1860	J. G. Clarke
1861	F. J. Clowes
1859	F. Colyer
1860	H. Coombs
1862	E. Cooper
1855	C. Copland
1860	J. Copland
1858	C. Cousins
1858	J. A. Cowen
1860	W. G. Cox
1861	H. C. Coulthard
1859	C. Cubitt
1859	J. G. Davenport

LIST OF MEMBERS OF THE SOCIETY

Elected.		Elected.	
1859	L. E. Davies	1860	R. H
1862	H. D. Davis	1861	G. P.
1859	B. Donkin	1861	J. T.
1862	W. D'Oyley	1862	C. A.
1859	R. Dyson	1861	H. H
1860	J. A. Eaton	1858	J. H
1859	P. Edinger	1859	F. H
1858	E. Edwards	1861	J. A.
1860	E. J. Eliot	1860	E. H
1858	J. Elliott	1860	J. S.
1860	J. Evans	1862	T. H
1860	C. Farrand	1862	J. H.
1858	F. W. Featherstonhaugh	1861	G. E.
1861	E. Field	1860	F. H
1859	H. Finlay	1860	C. F.
1856	J. Forbes	1859	C. H
1859	C. Gandon	1861	R. H
1860	T. Gandy	1859	J. Hu
1862	G. Garraway	1862	H. W
1862	W. Girdwood	1861	C. H
1862	G. Gjers	1860	J. T.
1859	J. Glynn	1859	J. Hu
1861	L. Golla	1860	F. M
1859	G. Gordon	1859	F. In
1859	F. B. Gray	1858	T. G.
1854	J. W. Gray	1862	P. Ja
1861	H. Greaves	1862	C. Ja
1861	T. Grove	1862	S. H.
1860	J. C. Grover	1860	P. A.
1858	J. Hadley	1862	P. Je
1861	J. Halford	1860	G. Jo
1860	G. Hall	1858	A. R
1862	C. Hanbury	1860	C. Jo

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.
Continued.

Elected.		Elected.	
1862	E. Jones	1862	G. Marshall
1860	H. Jones	1860	M. G. Martinez
1861	W. Jones	1860	W. G. McGeorge
1862	W. E. Jones	1862	J. Mees
1860	J. Keddall	1859	W. P. Miles
1855	J. Keith	1862	A. Millar
1861	C. F. Kell	1862	J. J. Miller
1859	B. D. Kershaw	1859	G. Molesworth
1859	J. T. Kershaw	1858	E. H. Moore
1854	R. King	1859	J. W. Moore
1862	R. Kirkwood	1861	J. T. Morgan
1861	E. B. Kirton	1860	F. Morris
1860	W. E. Kocks	1859	W. Morris
1858	J. Lacy	1860	W. Morris
1859	R. Laing	1856	W. T. Morrison
1861	B. Latham	1859	G. Muriel
1861	J. Laurie	1861	G. B. Nethersole
1858	W. H. LeFeuvre	1858	P. F. Nursey
1858	E. J. Leonard	1862	D. S. Nursey
1860	J. Leonard	1862	A. Ohren
1856	C. J. Light	1860	J. H. Ohren
1859	C. L. Light	1856	M. Ohren
1860	F. Littlewood	1861	E. Olander
1859	G. Livesay	1862	L. Olrick
1862	J. A. Limbert	1860	D. A. Onslow
1859	J. Lockwood	1859	T. Orchard
1861	A. Longbotham	1857	R. M. Ordish
1856	J. Louch	1856	T. Ormiston
1862	J. Lucas	1859	J. B. Paddon
1862	W. H. Lucas	1859	G. G. Page
1862	J. McCleary	1862	M. Parkes
1858	B. Martin	1858	W. Parsey
1861	B. W. Marshall	1860	E. Pemell

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Continued.

Elected.		Elected.	
1859	D. Pigeon	1857	W. H. Stephenson
1862	A. J. Pitney	1859	C. W. Stocker
1862	J. T. D. Porter	1861	W. Sugg
1859	B. L. F. Potts	1859	W. P. Sutherland
1859	J. T. Potts	1862	E. Swan
1862	W. Purvis	1861	L. Swan
1856	J. Quick, Jun.	1862	T. Swan
1860	H. Raincock	1862	T. Taylor
1859	G. Rait	1862	G. Temple
1862	E. Reynolds	1861	W. H. Thomas
1859	F. C. Reynolds	1861	H. L. Thompson
1860	E. Riley	1860	A. Thorn
1860	C. Robinson	1860	P. Thorn
1862	J. Roseby	1860	W. W. Tothill
1859	R. A. Rumble	1859	H. H. Treppas
1858	T. W. Rumble	1861	G. Trickett
1861	C. Sanderson	1861	H. Vavasseur
1862	L. S. Schmitthenner	1862	D. Van Heel
1860	G. Shaw	1862	F. Versmann
1860	G. P. Shearwood	1858	G. Waller
1854	G. Shillito	1862	W. T. Walker
1862	J. Shirley	1861	A. E. Walton
1860	D. Siebe	1862	F. Watkins
1859	E. Simpson	1862	A. Warren
1860	H. Smith	1860	D. Watson
1860	H. G. Smith	1861	S. Watson
1859	R. M. Smith	1859	W. H. Webb
1858	S. Smith	1862	E. J. Wells
1862	S. R. Smyth	1862	G. Wells
1858	W. Snell	1859	E. J. Whittaker
1862	J. Somerville	1860	J. Willcock
1859	A. E. Stephenson	1855	A. Williams
1854	H. P. Stephenson	1860	A. Wilson

LIST OF MEMBERS OF THE SOCIETY OF ENGINEERS.

Continued.

Elected.		Elected.	
1862	A. F. WILSON	1862	S. W. WORSSAM
1860	C. G. WILSON	1861	J. WRIGHT
1862	G. WILSON	1861	A. F. YARROW
1861	W. G. WILTON	1859	F. YOUNG
1858	F. WISE	1859	L. J. H. YOUNG
1861	W. H. WOOD	1861	J. YOUNG
1858	E. I. WOODHEAD		

December 8th, 1862.

ANNUAL GENERAL MEETING.

E. RILEY IN THE CHAIR.

The Chair was taken at 7 o'clock.

The Minutes of the previous Meeting were read, confirmed and signed.

Messrs. C. J. Light and J Hadley were appointed by the Chairman to act as Scrutineers for examining the Balloting Lists for the election of the Committee and Officers for the year 1863.

The Scrutineers handed their Report to the Chairman, who declared the following gentlemen elected as the Committee and Officers for the ensuing year.

COMMITTEE.

G. W. Allan,	G. Campion,
J. Amos,	W. T. Carrington,
R. M. Christie,	J. Lacey,
R. M. Ordish,	W. Parsey,
E. Riley,	E. Reynolds,
H. P. Stephenson,	F. Young.

A. Williams, *Hon. Secretary, and Treasurer.*

W. H. LEFEUVRE, Auditor.

A vote of thanks was unanimously passed to the Chairman, Committee, Auditor, and Honorary Secretary, for their exertions on behalf of the Society.

E. RILEY, Chairman.

December 8th, 1862.

SPECIAL GENERAL MEETING.

E. RILEY, IN THE CHAIR.

The Minutes of the previous Meeting were read, confirmed and signed.

The following Resolutions were agreed to:

"That the Society be divided into two classes, viz.:—Members and Associates,—and that of the present Members, those should be styled Members who pay an Annual Subscription of 21s., and those should be styled Associates who pay an Annual Subscription of 10s. 6d."

"That for the future, all Members, except those who reside permanently out of the United Kingdom, shall pay an Entrance Fee of 21s. and an Annual Subscription of 21s., and all Associates shall pay an Entrance Fee of 10s. 6d. and an Annual Subscription of 10s. 6d. That Members shall not be less than twenty-three years of age, and that Associates on attaining that age may pass to the class of Members, on expressing their intention to the Committee and paying the difference of Entrance Fee and Subscription."

"That Members residing permanently out of the United Kingdom shall pay 10s. 6d. Annual Subscription, and 10s. 6d. Entrance Fee."

"That at any General or Special Meeting of the Society, the scrutineers shall have power to reject all balloting lists not properly filled up."

"That all Members and Associates shall be required to pay their Entrance Fee and first year's Subscription, previous to receiving the benefits of the Society."

"Members and Associates whose Subscriptions are in arrear for two years to be struck off the register of the Society, but to be still liable for the amount of Subscriptions due."

"That the present Rules of the Society be altered by the Committee, in accordance with the above resolutions."

Signed, E. RILEY, CHAIRMAN.

SUBSCRIPTION ACCOUNT, 1862.

	£	s.	d.		£	s.	d.
Arrears due on 1st January, 1862	54	0	0	Received in advance in 1861 for 1862	1	10	0
Subscriptions due from 282 Members at 10/	141	0	0	„ for Subscriptions and Arrears	118	10	0
Admission Fees due from 80 Members at 10/	40	0	0	„ for Admission Fees	26	0	0
Subscriptions for 1863, being paid in advance	0	10	0	Written off in accordance wtth Rule 29	14	0	0
				Received in advance for 1863	0	10	0
				Balance Arrears due	75	0	0
	£235	10	0		£235	10	0

RECEIPTS AND EXPENDITURE FOR 1862.

	£	s.	d.		£	s.	d.
Balance in hand January 1st, 1862	9	8	7	By Rent of Hall	21	0	0
Received for Subscriptions	118	10	0	„ Advertisements	8	11	0
Received for Admission Fees	26	0	0	„ Engineer Journal	1	7	0
„ for Conversazione Tickets	0	16	0	„ Short-hand Writer	4	14	6
				„ Stationery and Printing Rules, Papers, &c.	40	8	6
				„ Postage	17	8	11
				„ Wages, Fees, &c.	7	2	6
				„ Premiums	5	3	0
				„ Expenses of Conversazione	33	11	0
				„ Sundries	3	3	7
				„ Balance Cash in hand	12	4	7
	£154	14	7		£154	14	7

Examined and found correct.

Signed, J. LACEY, } *Finance Committee.*
E. RILEY, }
W. H. LEFEUVRE, *Auditor.*

June 10th, 1862.

ANNUAL CONVERSAZIONE.

The Annual Conversazione of the Society was held in Lower Hall, on Tuesday evening, June 10th.

The Hall was arranged with a large number of models, wings, photographs, &c., which afforded a very pleasant instructive evening to a large number of the members their friends.

Visits to the Main Drainage Works.

The Society having obtained permission from the Engineer of the rd of Works, J. Bazellgette, Esq., to view the Main Drainage rks in progress,—several members availed themselves of the ortunity thus afforded them of inspecting this important under-ing.

The Members were accompanied over the Works of the Southern fall, on May 10th, by J. Grant, Esq., C.E.; and over those of the rthern Outfall, on October 23rd, by E. Cooper, Esq., C.E.

January 13*th*, 1862.

E. RILEY IN THE CHAIR.

THE ENCLOSURE OF LANDS FROM THE SEA, AND THE CONSTRUCTION OF SEA AND OTHER BANKS.

BY E. OLANDER.

The author would endeavour to lay before the society the details of con-
uction of Sea Banks, &c., taken from his own experience while engaged on
h works. He would divide the subject into the following heads—first, the
Enclosure Bank; secondly, the Shelter and Nursing Bank; thirdly, the
rsing Bank; fourthly, the Guide or Channel Bank; and lastly, the Sinking
Cradles for the filling up of gaps, &c. The most important of all is the
closure Bank constructed to take land from the sea In the construction
such a work the transverse section will greatly depend on the situation,
nerally a slope of not less than 4 to 1 should be given for the sea slope,
l the inner or land slope as steep as it will nicely stand at, say $1\frac{1}{2}$ to 1.

He thought some kinds of protection for the slopes used by the Dutch
gineers were not so good and more costly than those used here for some
ars, although they may be better adapted for Holland, where there are
ge plains of warp land miles before deep water is to be found, with a much
s rise and fall of the tide than we generally have on our coasts,
various parts of which we have an every day difference of 25 to 30 feet
t one of the tidal stations, Weston-super-Mare, a difference of 39 feet has
en recorded), rendering the force of the sea more dangerous to the banks.

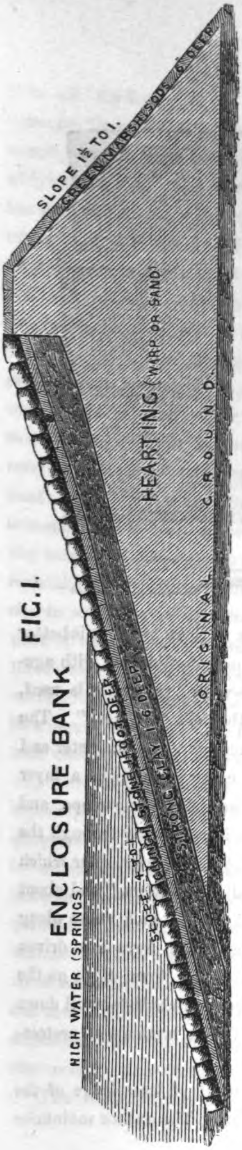
Drawing (No. 1.) is a transverse section of the best form of enclosure
nk. The hearting is generally composed of sand or good warp, the latter
ing far preferable, got by barrow roads from "floor pits," fronting the
oposed bank. Sea marsh sods would be better if a quantity could be
tained, but an acre of such material one foot deep would soon be taken
vay, and extra expense incurred in the increasing distance, and hence the
cessity to use such material as can be got by short leads in the front and
metimes the back of the bank.

When the hearting is of sufficient height and the slopes trimmed, the clay protection (1 ft. 6 in. thick) is cast on trimmed and well punned, care must be taken to procure the best kind of clay. The blue "butter clay" is not suited for this purpose, it being generally obtained from the slopes of creeks where in its natural bed it receives soakings every tide, and when exposed to the action of the atmosphere cracks and forms dangerous openings, and there is also a difficulty in working it to an uniform slope through its soft nature: it will run down to the toe. Good clay can be obtained generally in the bay of green marsh, and is very good for this purpose.

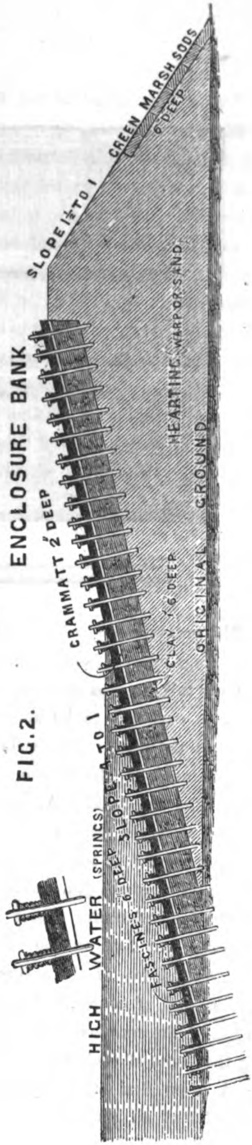
After the clay is nicely trimmed on, a complete layer of green marsh sods or "flags," should be placed on the clay 6 in. deep, or more if possible, well jammed together, on top of these a layer of Clunch Stone (chalk stone is good) 1 foot deep. Care should be taken that good packers are employed as the strength of the stone-work depends much in the manner each stone bites the other, also in producing a flat top offering less resistance to the action of the waves.

Such a bank should be adopted where strength is required, and it will be seen that, if made strictly according to specification, it would require a powerful sea to do any amount of damage. It may appear a strong work where only a head of water of 8 feet has to be met, but the sea is very strong at times, and would, in an exposed part, cleave those stones away. When once the water touches the "hearting" which has become dry, a gap will soon form, and the water rush through. A better idea cannot be given than by supposing the inside of the bank to be composed of moist sugar.

Drawing No. 2 shews a Dutch mode of making sea banks and method of protecting slopes. The clay upon the hearting will be the same as already described, and on top of this (instead of sods) straw matting, called "crammatting." The process of covering the slope is as follows:—supposing that we look up the slope, a layer of loose straw 1½ in. thick is evenly distributed up and down the slope, after which straw bands are laid horizontally along the slope. The crammatter, or man who understands the work, by the aid of a tool, shewn on Drawing No. 3, thrusts the band in the form of a stitch into the clay through the loose straw at every four or five inches. Before the second stitch is performed the workman will give the band a twist so as to keep it round, and then the thrust is repeated. (64 stitches go to the square yard).

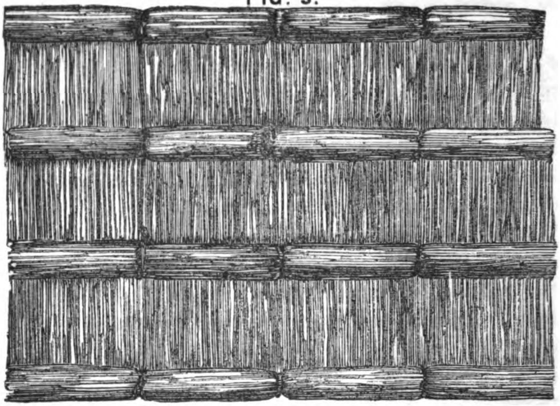


ENCLOSURE BANK FIG. I.



ENCLOSURE BANK FIG. 2.

FIG. 3.



This crammatting will rot in two, or at the most in three years, it is better to use flags instead, being a permanent material and consolidating with age.

Over this, in lieu of stone, a costly "fascine-work" protection is used, which is supposed to be an improvement on the old "faggots." The process is as follows: The fascines are 7 ft. 6 in. long and 6 in. diameter and 1 ft. diameter at the broom end, so that when compressed form a layer about 6 inches thick. At every 1ft. 6 in. up and down the slope and 1ft. 2in. along the slope, pointed stakes are driven into the clay through the crammatting 3ft. in length, and at an average of 1½in. diameter, after which long twigs of about ¾in. diameter, technically called "binders," and about 8 to 10 feet in length. These are wound in and out of each stake along the slope (say five on top of each other), after which keys are driven through the top of the stakes, and each stake driven down tight on the binders, and, of course, tight on the loose fascines, which fastens all down on top of the crammatting. This is one of the Dutch methods of protecting the slopes of their sea banks.

A great deal of money has been lost by a want of knowledge of the ground that an enclosure bank may be built upon. The author maintains

an undertaking of this kind should not be made on "silty" or
rpy" ground, and not even on samphire or crab marsh ground, which
s next in height to green marsh; bnt that the only site that can pos-
pay the proprietor or a company, and particularly the contractor, is at
dge of green marsh, so far in as to leave a cess or foreland of forty to
feet, and when commenced should be ordinarily ploughed, causing a
ed surface to receive the "seat" of proposed bank. If, on the contrary,
attempted when sea marsh does not exist, and seawards of green marsh,
n an exposed position, where much of back water must necessarily ebb
the difficulties will be great; not so much in the construction of the
osed work as in *keeping the original ground the bank is to be built*
. For should a gap occur the cost of re-filling is so much increased,
deeper the gap becomes by the increased length of the slopes; and,
ring again to the safety on the green marsh, is obvious from the fact
it all forms at a certain height above low water line, and where there
t sufficient head of water to render it dangerous to its working; also
material being of a very strong and tenacious nature meets the increased
tance of the tides. The exposed position on the low grounds will give
to several causes of failure; and it requires the greatest care on the
of the engineer to foresee the effect that the powers of wind and wave
e over the work of man. The apparently strong facing with rigid thick
e protection, and a good flat slope, has been shattered and carried away
very short time. The 6 feet wave, with the wind obliquely on the slope,
clear away the stones. Another dash will scoop out a quantity of
work and get to the inside, and a great loss will be the consequence,
ecially if the enclosed portion is tilled and worked up for agricultural
poses.

In stating the safety and profit of constructing sea-banks at the edge of
green marsh he refers to the enclosure of lands, and not to exclude the
ctice of carrying forward such a work two or three miles, if circum-
nces admit of such a requirement. A strong sea-wall may be required
shut out the sea for the construction of waterworks, as docks, slips, &c ;
t then the cost is part of the works to be carried on within. This is ab-
utely another question, and is in itself a matter of cost for *sea-walls* for
y special undertaking.

The bank already described as being one of great strength, and which

would require small outlay in the maintenance (a great consideration), would cost about £80 per chain forward, therefore requiring about 300 chains to enclose. 1,000 acres would amount to £24,000. When enclosed the land ought to fetch £45 per acre—equal to £45,000, leaving a residue of £31,000 as profit.

Comparing the cost of the two methods of constructing the bank already described, will shew that the one in Drawing No. 1 possesses advantages over that shewn in No. 2. The hearting will cost the same, clay same, the green marsh sods can be done for 2d. the super yard, the Dutch crammatting costs 6d., the stone packing in place would be well paid at 2s. 6d. per super yard 1 ft. deep, that being the price of the fascine work, shewing a small reduction in favour of No. 1 Drawing, but this is not the main consideration. The first design is strong and permanent, which would resist any sea in the position already named for its site, whereas in the second case the sea slope is but temporary protection and easily damaged by the waves.

Shelter and Nursing Bank.

The bank under this title, and which the author saw constructed, was

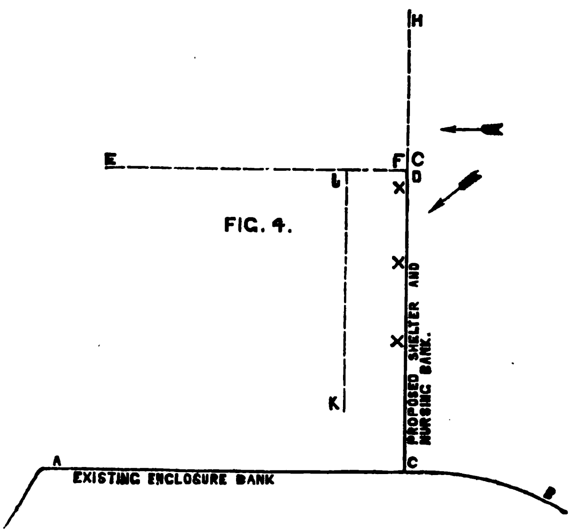


FIG. 4.

tended to answer two purposes. First, that of sheltering and preventing amage to an existing enclosure bank, and secondly, in assisting nature in e laying up of land for future enclosure. The one desirability viz., that of nursing" (as it is technically called) and assisting nature in her sea deposit debris (probably from the inland rivers, drains, and coast of the estuary) not attained, and such an undertaking has no claim to the title of nursing."

Supposing *a, b,* the boundary of an old enclosure work and that further aims are required seawards, *c, d,* is the proposed sheltering nursing bank.

The tide, for example, is in direction of arrow, and the wind in direction dotted arrow, there cannot exist a doubt that *c, d,* would materially elter the old bank *a, b,* and for this purpose it has its advantages, when in out to a certain length when the old sea bank is too weak and requires ontinually repairing, and at times in danger. This would occur when o small an outlay is given in the protection, shewing that an enclosure ank ought to be made at the onset sufficiently strong, and the requirements a shelter bank unnecessary. But at the same time the bank *a, b,* might y circumstances be weak, and hence the necessity of an outer protection ank. The most prominent advantage to be gained is that if maintained it ould ultimately become one side of a new enclosure.

The bank *c, d,* having been constructed, let us see the result of the second equirement, viz., that of assisting nature in depositing or the laying up of varp for future enclosure. The simple fact borne in mind, the narrower you nake your river the quicker the rate of the tide, and by the same principle hat a "cut" is made in an estuary to improve navigation and to obtain a reater fall by an increased scour due to the extra rate of the tide, so by utting out banks from a coast the same theory will hold good, certainly to small extent, but to an extent sufficient to interfere with the process of 'laying up" already mentioned. In the vicinity of the inside of the bank *c, x, x,* the flood and ebb tides are considerably increased. Now, therefore, s the warp already deposited is entirely subservient to the rate of the water assing over it, this increased rate will take away that which would have emained, had it not been for the bank that caused the extra scour. The uthor had seen a rich deposit during low "neaps" when a good wind in he "springs" causing a high tide, and an increased rate of ebb has taken all away again, quite clear to the original surface "warp" deposit, collecting in

an estuary is seen in its theory by considering the water leaving the deep sea beyond and coming up a flat plain of little depth, and when reaching this point passes on slowly, coming at last to a stand at the edges of the green marshes. The matter carried along by the tide which did not sink through the troubled water, but becoming quiet, those particles which produce good land leave themselves lightly on the surface. Now by raising such impediments as bars or cradge banks, commotion takes place, and ultimately an increased rate of tide. Hence the very particles lightly settled upon the top of its preceding deposit are carried away. The deposit is on sufferance to the rate of water flowing over it.

Having taken careful levels on three lines after the bank was completed, the result, when plotted, confirmed the previous statement. The most prominent result, and that which actuated him to investigate the matter more closely, was that on the line *e*, *f*, a good depth of material had scoured away in the form of a wedge the thin end at *e*, where the bank could not practically affect the land. The same result shewed itself on the line *g*, *h*, but not to such an extent, and on the line *j*, *k*, instead of new deposit where there ought to have been at least 1 ft. of new warp, an average of 4 in. in depth was washed away, the ultimate result was that small cradge banks had to be run out at right angles from the inner slope to prevent small slips that had occurred, and small holes repaired with clay and made even with original slope again.

It is very necessary in carrying forward such a work to keep the "floor pits" as distant as possible from the "toe" of the slopes, of course the nearer the less cost per floor, as the barrow roads have a less "lead." By excavating too near only draws the ebb water to the bank and forms a permanent channel for the ingress and egress of the tides. If the pits are 3 ft. deep at the total length of the bank, they must of course tend to form flat rivers each side, and as the work proceeds seawards great difficulty is occasioned. The last water drawing into the made river is carried along by its fall and rushes round the end, and scours the original surface; it is, therefore, very necessary to make an apron of good clay, driving it forward as the bank works are pushed forward, 1 ft. deep the entire length and width of the bank, which will meet the rush of water in the flood and ebb tides.

The author has seen a bank of this description constructed a mile long, with its progress day by day meeting with increased resistance as it is

reased in length, shewing as it gets to the lower ground the compound
ficulties it has to encounter. Small rivulets for the first ¼ mile will form
the end, increasing at the end of the ½ mile about 5 to 8 feet deep, and
ing these up increases the cost considerably, until the sea, with its usual
ermined character, made a breach at the end of unusual dimensions, just
show we were infringing.

If it were required for the bank just described to be carried forward
other mile, the cost would increase in the construction every yard forward.
r the first 20 chains, a layer of clay in the front as an apron, 1 ft. 6 in.
p, with flags if possible; if not, with the best clay conveyed to the spot
flat bottom barges, and discharged at high water, trimmed when the
ter had left. This material costs more than the hearting—twice as
ch; but it is not loss, by reason of its becoming part and parcel of the
t of the bank, and reducing the sectional area. This clay apron ought
be in advance about 3 chains. Proceeding from 20 to 40 chains, the
ne care should be taken, but increasing the clay to 2 ft. in depth. From
to 60 chains, 2 ft. deep of clay, covered with temporary fascining, *i. e.*,
got or furze bushes staked down about every 5 feet in line with the bank,
at care and examination as to an uniform thickness of clay, as by this
ne considerable difficulties will arise. The last 20 chains completing the
le would require a very strong apron, at least 5 chains in length, and
out 20 feet beyond each side of the toe of slopes. This pushed forward
th 2 ft. 6 in. of clay sods, or the very best clay, if the sods cannot be got,
vered with complete fascine-work made as well as if for a slope protection,
er this, on the average, a foot of clunch stone packed as closely as pos-
le. This done, the sand hearting work may proceed seawards. Every
ne the rising tide prevents the works proceeding, the navvies should be
ployed the last thing in trimming the end slope with clay up to high
ter line, and when commenced again this clay may be left and included
hearting. Not so with the apron. The temporary fascines, stakes, and
nders, with the stones on top, may be removed and re-used for the same
rpose, only leaving the clay to make up as part of the sectional area.
hen the mile is finished, the apron, with the stone on top, should be made
out 2 chains longer at the end of the bank, and left to keep the toe of
pe safe and secure. It will therefore be seen that the further the bank
ts from the coast, the more difficulties present themselves, even if the

low water line may be 10 miles distant, and the fall in the ground does not exceed 12 inches the mile. The back water held up by the greatest length of bank produces the greatest rush of water round the end. If these banks can be made pointing as near as possible to the direction of tide, it would save much trouble and cost.

Nursing or Warping up Bank.

The sectional area is simple, built about 5 feet in height above the original ground. The hearting of sand, covered with clay, then fascining, and, lastly, stones on the top, made round so that the sea can pass gently over it when arriving at the top. (See Drawing No. 5). In every respect, with one exception, do the preceding remarks relating to the shelter and nursing bank, with reference to the laying up of "warp," apply in this case. Being only a few feet from the sand, the sea every tide covers it, and when rising falls over the top, not if there is a good fall in the land it is built upon. This rushing over is objectionable for its maintenance, causing holes and slips on the inner side. Careful consideration on this subject leads the author to the conclusion of little profits arising from making these banks, and whatever benefits may accrue unknown to himself, they cannot be made to produce one-tenth of their cost, and he has no hesitation in condemning them as unnecessary.

An improvement might consist in constructing impermeable shallow enclosure banks to receive the water every tide, and to leave the enclosed portion to fall when it had receded. Let the bank be made 4 to 5 ft. high above the ground. The water docked up remaining still, and the alluvial matter suspended, would settle, and by the time the next tide came, bringing its fresh supply, the water remaining would be displaced or intermixed with the larger supply, would leave an entire basin to do its work again in the process of raising the land ultimately to the level of top of cradge bank. By these means, all scour is avoided, and a good time is given for each periodical supply to get rid of all the alluvial soil it contains.

Guide or Channel Banks

are very difficult to construct owing to their being entirely submerged at high water, and, besides, can only be constructed at low water; owing to this the cost is considerably increased as the men must be paid by the tide. Although recommending clay sods they cannot always be obtained plentifully, as the marsh lands in the vicinity of an estuary

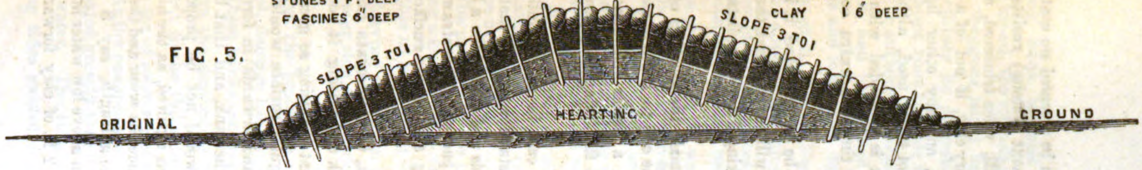


FIG. 5.

GUIDE OR CHANNEL BANK

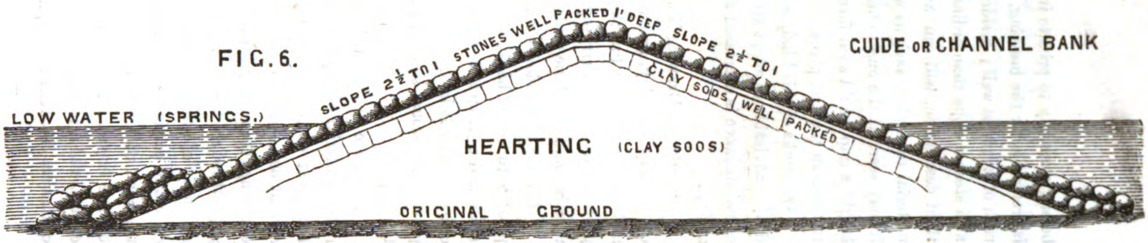


FIG. 6.

belong generally to private individuals. If they can be procured no material is preferable for the hearting, no material (coming next to stone) resists the rush of water so well; besides when cast in they will, when trimmed, stand at a steeper slope than ordinary clay, indeed ordinary clay, if not of a very tight description, will run away into a flat slope, and any other lighter material than clay, such as warp, silt, &c., ought not to be used, although it may seem at the onset cheap, but when the bank is proceeded with any height a gap would soon form, and cover in a short time the extra cost of the sods in the first place.

On works of this kind, where so much risk is to be apprehended, it is, no doubt, advisable to adopt strength at first; also, it will be seen, that the cost of maintenance is decreased after completion by making the work substantial at first.

Referring to Drawing No. 6, it would be well to make the hearting of sods on the very best clay, and with this material a slope of ½ to 1 when cast in and above low water line the work may proceed in a better manner, *i. e.* properly trimmed, carrying up at the same time 1 ft. of clay sods jammed together and the stone protection may rise also.

The toe of the slopes would be of loose stones cast in as carefully as possible to line of bank, doing this tends to form a stay for the soft material inside and to keep it in place. Between the clay sods and the stones a layer of loose straw is laid, upon which the stones can be packed. This straw is to prevent the stones sinking into the clay and forming an uneven surface on the slope.

There are two methods of commencing this work, first, by boats casting in the material at any point in line of proposed bank and raising it bodily; but great objections arise to this system on account of raising so great an area at one time, and hence it will be seen, an irregular surface would but encourage the tides (continually passing backwards and forwards) in forming gaps through the new material to the seat of the bank, and that being generally of sand is soon scoured away. Now it would not be proper to raise any portion of the work until the gap had been repaired, as the higher the bank the greater head of water held up, and hence the scour and the gap become larger. The second system would be to take a length, say 3 to 4 chains, and raise such length horizontally, and when above low water line to commence the next length, always casting in about 2 ft. of clay forward of

coming bank to meet the extra rate round the end. As the bank lengthened, the top being about 4 ft. wide, a small tramway carrying one yard waggons might be used to convey straw, clay sods, and even stones, to facilitate its progress, and being the highest point could work up to the latest time the tide would allow.

The author saw the advancement of such a bank from day to day. Before this it had been raised on an average 2 ft. above low water line by large stones and loose clay, deposited by large hopper barges carrying 30 to 40 yards each, and at low water the longitudinal surface presented a very jagged appearance with several gaps, one of which was very large. Nothing else could be anticipated by proceeding with the work in this manner, the irregular surface, and more especially the stones, presenting great obstacles to the progress of the work.

On top of this uneven surface the work was commenced, sometimes with clay, but chiefly with sods, all this material brought by flat bottomed barges cast on and trimmed to a slope with a horizontal top about 6 ft. above low water. This bank, at such a height, is but the commencement of a larger one, for the purpose of continuing the cut of the estuary, and to form, ultimately, a bank for enclosure of land. These matters depend, of course, on the first designs.

The position of this guide-bank renders it, when complete, in danger of having a breach cut through it, owing to the great area of back water held up, and this at last ebbing out always around the end when below the level of top, leaving a basin on the inner side; the flood tide again coming in at the outer side and pouring over, causing a fall and running down the inner slope.

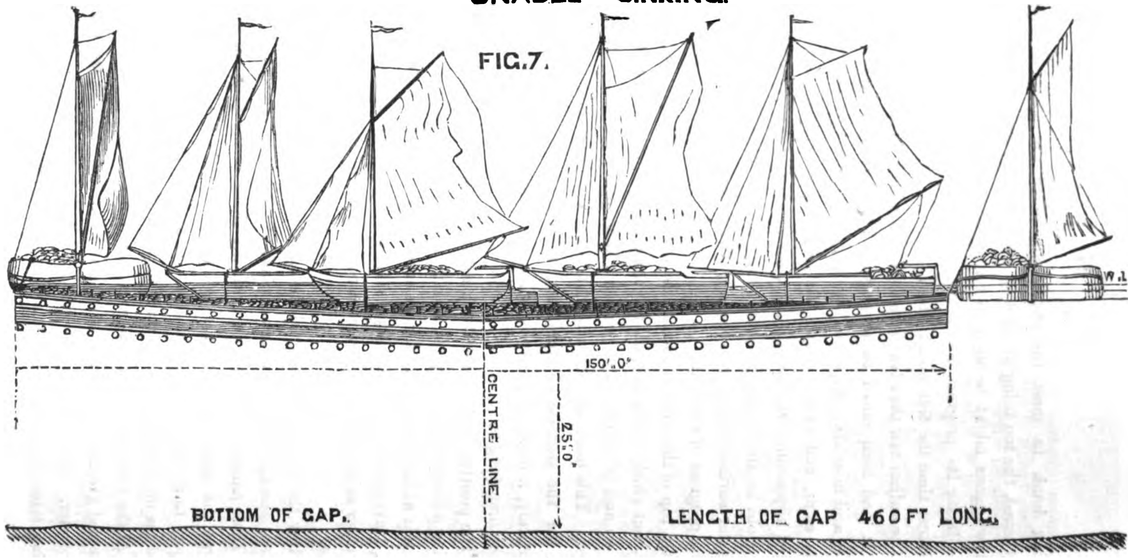
But the protective materials being of the best quality, as already mentioned, damage has not yet taken place.

These banks constructed to guide the tide into the channel, and to discharge the descending tide through the low sands, the river slope is also subject to the full rate of the tide. Consequently, it is important that a good toe of loose stones and firm material underneath should be used.

At the commencement of this work, several breaches existed, one of which exceeded greatly the others. It was 460 feet long, and 24 feet sounding at low water. The tides rushed through with great velocity; and while the spring tides existed, it was almost impossible for a boat to pass along the

CRADLE SINKING.

FIG.7.



er side without being carried through. To fill this up, and complete the k evenly with the other portion, was rather a formidable undertaking. vas considered by professional men a difficult .work, but it was done tually and completely.

The bottom of this large gap was composed entirely of sand. Various iods might be thought of for filling up this large hole. In England e has been but one way, that of casting in indiscriminately all sorts of rial at any point (sometimes to be carried away again), without system efined quantity. Let us see the result of this plan. It is a sandy om, and the area of gap just due to the quantity and rate of water ng through it. At one end of the gap a quantity of material is tipped ay clay, and, being stronger to meet the current, remains; the sectional is reduced, but the rate and quantity of water the same, the sand being veakest, and at the mercy of the water, must be displaced, and practi- as much in quantity as the clay tipped in. This is very likely to r at the toe of the clay material, and the consequence is that it slips, only fills up the hole where the sand is taken away. Provided even the clay is raised to a good height, there would be very little chance of maining in such a breach as the one in question. The material requires ing together to form one entire consolidated body. This has been mplished by the system of cradle sinking, and he would now endeavour xplain the entire operation.

In reference to drawing No. 7, great credit is due to Mr. Müller, a gentle- who had the management of the works, for his indefatigable exertions ringing the system of cradle sinking, in the filling up of gaps, to perfec- in this country. About 25 of these were sunk in different parts of the ks, and not one failure to be recorded in the whole. This part of the k is a Dutch engineering importation about two years oid, and its ess is entirely owing to the exertions of this gentleman.

As a cradle so large as the breach could not be worked effectively, it necessary to give the bottom a coating of clay sods. This was done all with a good width, and also a good depth; instead, therefore, of a ly bottom, it was composed of green marsh sods. Before describing the ations of sinking, it will be necessary to detail the materials and con- ction of the cradles. The first one used, and the largest, was 150 feet by 45 feet wide, and about one hundred workmen were engaged in the

sinking. The whole of it was made of fascines, stakes, and binders. The fascines before described, 7 ft. 6 in. long, were lapped and intersected into one another to form a rope of about 6 inches in diameter, the intersected parts bound strongly together with osier twigs. This rope, made of birch (willows being preferable), was manufactured on a raised rack made of two uprights and a horizontal bar to rest the rope on, so that the workmen may get their arms underneath for binding them together. A sufficient number of these ropes is all the preliminary work before commencing to construct the cradle.

A flat of sand in the vicinity of the gap was chosen, and at such a height that the tide will float the cradle when complete.

Transverse ropes of fascines were laid about 3 feet apart on top of these longitudinally, and the same distance apart at right angles, the same thickness of rope; all these were fastened at their crossings by cheap hempen rope. This properly done, three layers of loose fascines, breaking joints with one another. On top of these loose fascines (see drawing), precisely the same as the underneath two layers were repeated, but reversed, *i. e.*, the transverse ropes on top, making in all four depths of ropes and three layers of loose fascines. Again, on the top of these, in various divisions on plan, binders were staked down, making it as rigid as possible. Besides this, several mooring posts were made of stakes, the stakes coming out at the bottom, and giving a jagged surface to bite into the clay.

When manufactured, and the spot where it was to be sunk properly beaconed out, the floating and mooring was the next object. This was accomplished slowly by anchors. Boats carried them at a distance, and dropped them, and they were then hauled upon, to be repeated again until it was brought into the exact position. This was a short time before high water. The flat-bottomed barges, loaded with sods and stones, followed in the rear. About eighteen of these, and three lighters of clunch stone, surround the cradle, and care was taken that they were moored or anchored independently of the cradle.

Slip ropes from each of the barges were passed through small ropes, with smooth iron thimbles, attached to the edges of the cradle, and brought up again with a slip knot. After this, orders were given to cast in the sods and a few stones as evenly as possible, so as to prevent distortion. This was to be feared, and great care was to be taken in evenly distributing the

terials on the surface of the cradle, until it disappears below the water. discharge of sods and stones still proceeded until about 3 to 4 feet below surface, and at this time the fleet of barges take the strain, and the dle is prevented from sinking by the ropes. At this time, it was neces- to let go, and the drawing shews the cradle in that position. To do effectually, all the ropes must be released simultaneously, by a pre- usly systematic arrangement among the workmen; for it will be seen t any mistake on this score on the part of one man in neglecting to ase at the proper time, the strain on the one or two ropes would tend to ple over and crumple up the flat sinking bulk, that ought to sink hori- tally. Nothing of this kind occurred. When the order was given, the es were released, the barges upheaved, and the cradle went down satis- torily. Immediately the ropes were loosed, with all possible speed sods stones, and particularly the larger pieces of clunch stones, were cast in, that whatever tendency the cradle might have to collapse, the large ntity of material contained in the twenty-one barges, delivered by about hundred workmen, would prevent anything of the kind, and the extra ntities discharged quickly completed the operations. This job occupied and a half hours, and took about 170 cube yards of sods and 120 tons cliff stone, and cost about £170.

DISCUSSION.

Mr. Müller fully concurred with the author that a stone protection for slopes was more effective than a wooden one under certain circumstances, t it did not follow that it should be always used in preference. For tance, a wooden protection will allow a steeper slope than a stone one, d it is a question whether a steep slope does not possess some advantages er a flat one when exposed to a rough sea: the spot may be too much posed for a flagging protection, and not enough for a stone protection. often happens that, after the construction of the banks, the land in front ll silt up. A wooden protection may be renewed twice for the same cost the first outlay for a stone one, thus rendering in some cases the wooden otection preferable. Frost affects many kinds of stones, and when this ppens the first gale will often destroy the whole facing, and stone very ten is difficult and costly to obtain—while wood is usually more easily tained, especially in the flat countries where the reclamations are made

he therefore thought wooden protections were the cheapest, and nearly always to be preferred. He did not agree with the author respecting the nursing banks, but considered, where they were sure to be of service, they should not be raised more than 12 or 15 inches above the surrounding level. The principle of sinking cradles to fill up holes he considered the best, however expensive they might be.

Mr. Bryant suggested an upright bank, constructed with a double row of short piles, with transverse bracings as a sea wall. The system of cradle sinking he considered very expensive, and thought the ordinary method of throwing in the stones might be adopted at a much less cost.

Mr. Thorn preferred a flat slope, and thought a good sea wall might be constructed with large masses of concrete, formed of rubble stone cemented together, and placed on a firm foundation.

Mr. Müller said a stone protection was used largely in Holland, but differed from the mode proposed by the author, the slope of the bank being formed with clay 12 to 18 in. deep, then two courses of bricks, covered by 8 or 10 in. of brickbats, and upon these 12 to 18 in. of stone, usually Bagolt, from Norway. In loading the cradles with stones, &c., it was impossible, in strong currents, to keep the boats in the places required so as to load the cradles uniformly; but the cradles, being flexible, adapted themselves to the form of the ground they were sunk on, and the tide levels the stones between the wattles. Each cradle is about 3 feet high, and costs 7s. to 8s. per cube yard.

Mr. Morris thought holes could be as easily filled with clay, &c., thrown from barges, as by the more expensive mode of the cradles.

Mr. Louch described a method he had seen adopted for making a sea bank at the Sunderland docks. The earth that was excavated was thrown over towards the sea, thus reclaiming ground; groins about a quarter of a mile long, made carefully of stone work, were thrown out, and the tide washed against them, causing a quantity of silt, &c., to be constantly collected by them, thus reclaiming many acres of land.

Mr. C. L. Light said, that one of the most important considerations in the reclaiming of land and the construction of embankments, was economy. It was quite possible to construct sea-walls and embankments of every kind, but in all such things the expense was the primary consideration. He should have thought it would have been advisable to have shewn some

e Dutch methods. With regard to Mr. Thorn's suggestion it, of course, quite possible to fill his boxes with concrete manufactured on the spot, ts great expense would entirely preclude any such plan being adopted—cost would be enormous. As regarded sea banks, he did not think it able, where there were heavy tides, or where there was the action of g seas, to make them of a greater degree of steepness than shewn in iagrams. The sea walls on the Dublin and Kingstown Railway had blocks of masonry built in like a wave-line, and although expensive, most desirable character. He thought the best materials for the con-tion of these banks was chalk, where obtainable. He had heard of a od which he thought to be very practicable, the proposition was to sink ravitation a mass of masonry built on a timber platform. Although uld be very expensive there was no doubt it would be very effectual very durable.

Ir. Olander, in reply, said he could not agree with Mr. Müller, that a slope would stand the action of the sea better than a flat slope. The rience he had had in these matters fully confirmed his opinion in favour ie latter. Without theorising the question it seemed clear to him that ep slope must be more effected by the rush of water, and consequently er risk incurred to the face of the slope. With regard to the fascine-: he had, and always should, consider it but a temporary protection; although to a certain extent the stone is affected by severe frost, still so much as to render it an inefficient, permanent work. Then, again, nportant consideration is, that its cost but slightly exceeds the fascine-, one being permanent, the other temporary. He still maintained his ion in reference to the uselessness of "nursing banks," that if adopted should not be more than 5ft. high, but he thought 2ft. or 3ft. prefer-. He thought Mr. Bryant's suggestion for filling up gaps by casting rge stones could not well be adopted, and without other material com-d next to impossible. The large stones in the bottom of a gap com-d of sandy soil, would displace as much as is due to the increased scour. Thorn's suggestion for a box to be filled with stones is only an exaggera-of that proposed by Mr. Bryant; such a box would be as compact and as much resistance as a stone of the same size. The great desideratum 'cradle sinking" was to produce a compact consolidated body, tied ther by the tenacity of the clay sods, and all the materials into the

D 2

interstices of the cradle itself. In the first place a thin layer of clay must be deposited all over the bottom surface to prevent scour. A gap might be filled up with clay sods, but he thought Cradles the best and cheapest. The area of a gap is due to the rate of water passing through it, depending also upon the nature of the soil. By reducing the sectional area the rate is increased, and consequently the scour. Means and proper material must be found to meet this or the gap cannot be filled up.

The Chairman in closing the discussion said, he thought the use of stone or wood for sea-walls would mainly depend upon local circumstances and the cost of the materials on the spot.

February 3rd, 1862.

J. AMOS IN THE CHAIR.

ON THE ACTION OF PEATY WATER ON A BOILER.

By E. RILEY.

The author offered some remarks upon the action of a peaty water upon a boiler, hoping that it might elicit a discussion on the important subject of the action of various waters upon boilers.

In 1854, his attention was directed to a boiler belonging to a mountain colliery engine in South Wales. This boiler had been placed *in situ* in 1849, and was made with 9-16 Staffordshire plates. From the time of its erection, it had been noticed that when the boiler was cleaned out, or when the gauge cocks were tried, that the water was always coloured red, to such an extent that, in the latter case, all objects near the cocks were covered with a red incrustation of oxide of iron.

The water for the supply of the boiler was drawn from a pond, which collected the water running from the adjacent mountains. The water was turbid and dirty. A sample of it was analysed, and gave the following results:—

Composition per Imperial Gallon.

	Grns.
Silica	·405
Peroxide of iron	·240
Sulphate of iron	·201
Alumina	·126
Phosphate of lime	·127
Sulphate of lime	·350
Sulphate of magnesia	·360
Alkaline chlorides	·487
Sulphate of soda	·258
	2·554

Traces of copper, and a large quantity of peaty matter.

On looking at the analysis, the following points may be observed: First, as regards the amount of silica, alumina, and iron, it is evident, from the turbidity of the water analysed, a large portion of these ingredients are held in suspension as clay. As regards the iron, a certain amount exists as peroxide, and is held in solution by the peaty matter present.

The other portion exists as sulphate of iron (green vitriol), and is formed by the oxidation of iron pyrytes in the peat. The trace of copper is also derived from the oxidation of copper pyrytes; the quantity of this is, however, very minute. It could only be detected by evaporating to dryness one gallon of the water.

The deposit in the boiler in a semi-liquid state was examined. It consisted chiefly of oxide of iron, with a very appreciable amount of copper, and the other salts in the water in a concentrated state.

After the boiler was cleaned out, a minute inspection of it was made. It was found that, commencing from the water line to the bottom, the boiler was considerably acted upon, more especially at the bottom, the action decreasing upwards in wavy lines. The piece of plate exhibited is from the bottom, and it will be seen that there are holes completely through it, from 3-16ths to 1-16th of an inch in diameter, and it seems remarkable that a boiler could work at a pressure of 60 lbs. with such a plate, or that it would hold the water. In the inside of the boiler, however, were found small rounded pieces of shale and coal, which were forced into the holes; and although the boiler leaked, yet it could be worked. Amongst the deposit was also found small thin scales of metallic copper, some nearly one-eighth of an inch in diameter; and also pieces of oxide of iron, with a small scale of metallic copper in the centre.

The action of the water on the boiler may be attributed—Firstly, to the action of the minute quantity of sulphate of copper, which is immediately decomposed by the iron metallic copper being deposited, and an equivalent quantity of iron dissolved. Secondly, to the sulphate of iron, which is soon decomposed into a basic sulphate with the liberation of free sulphuric acid; this action is much facilitated by the small particles of metallic copper, which form a galvanic circuit with the iron. Thirdly, to the large amount of peaty matter which contains organic acids—the action of the acids being facilitated by the galvanic action set up between the iron and copper.

The best method to preserve the boiler would undoubtedly be to use, for

a time, a hard water, and allow the boiler to scale; or, if a hard water could not be conveniently obtained, to add chalk or lime, and sulphate of lime, so as to obtain an artificial scale. The action of the above water is chiefly due to its being so pure, and free from lime salts; whereas, if the boiler scaled a little, the above water might be used.

These remedies were suggested, but the boiler belonging to a large company, it was replaced, and the action is going on in the new boiler at the present time.

The author concluded by stating that he thought it questionable if pure waters were well adapted for steam boilers. He considered that a small amount of lime salts were beneficial, as they were deposited on the iron, and preserved it; but when they existed to a large amount, they were of course very prejudicial. If possible, it would be advantageous to use a hard water for a time, then to use a soft water.

DISCUSSION.

Mr. Waller asked for information regarding the best means to be adopted for removing or preventing the deposit in boilers.

Mr. Greaves considered the subject to be one of the most important that could be brought before the Society. He believed that boilers constructed with a proper circulation for the water, that is, where a proper circulation of the water could be kept up, would only be affected with a very slight incrustation. He had 25 years ago constructed a small circular boiler, with water tubes, the first made in this country. Between the fire-box and the outer case was placed a piece of sheet iron around the fire-box and the tubes, by which means he found the circulation was so completely established, that when the boiler was pulled to pieces after being in use 12 years the fire-box was scarcely coated, and it was evident that the slight incrustation that was found was of a recent formation. Some time ago it had occurred to him that if the fire-box was corrugated, whether of copper or iron, there would be a certain expansion and contraction of the metals which would crack the incrustation as it occurred. This could be proved with a piece of cardboard covered with lime, by which it would be seen what a very slight contraction or expansion would crack the lime. He had found this plan answer well, and the boilers when examined, the incrustation was very slight. He was fully satisfied that a perfect circulation of the water in boilers would materially prevent incrustation.

Mr. Morris thought something more than a perfect circulation of water was required to prevent deposits in boilers. He had never seen the iron corroded, but was well acquainted with deposits of carbonate and sulphate of lime, but had not found them to have any effect upon the iron unless they were allowed to accumulate very much, when, of course, the boiler would be burnt by the fire.

There is considerable difficulty in removing these deposits, which form a hard scale which adheres very tenaciously to the iron, to prevent this incrustation he had tried many remedies; but used "Buckingham's Composition," which was found to answer well. The boiler required to be cleaned out every six months, when a brown mud was found at the bottom, which was easily removed.

In a small high pressure boiler he had managed to deprive the water of its earthy carbonates by admitting a very small jet of cold water into the exhaust pipe of the engine, where, mingling with the waste steam, it condensed a portion of it, whilst the steam, by raising the water to boiling heat, drove off the free carbonic acid, and the neutral carbonates were thrown down on the sides of the pipe (which was made large enough to allow it to accumulate), the water then ran down into a tank, whence it was pumped into the boiler at a temperature of about 200 degrees; added to this, the partial condensation of the waste steam reduced the back pressure on the piston, and the result was a saving of half the fuel, and the boiler remained quite free from incrustation.

Mr. Louch expressed his opinion, that, in many cases where corrosion had taken place in boilers where surface condensers were used, were due to small particles of the copper or brass from the tubes of the condenser, being carried into the boiler, and not, as was generally believed, to a galvanic action having its origin in the condenser. He recommended that great care should be taken, in fixing surface condensers, that all filings and other loose particles of the tubes should be entirely removed. He also recommended that, in cases where the water formed a rapid incrustation, it should be submitted to chemical analysis, and the proper antidote could then be selected—it being absurd to imagine that one description of boiler fluid, or other scale preventer, could be applicable to all cases.

Mr. F. Young said the owners of steam boilers had a difficulty in judging the quality of the water used for their boilers. This difficulty could be

avoided by the use of a small pocket apparatus invented by Mr. Danchell, of Red Lion Square, which contained tests for all combinations of water. As regarded the compositions recommended for preventing incrustation, he thought the remedies worse than the disease. He was of opinion that rapid circulation would prevent incrustation; and if reference was made to a paper read before the Institution of Mechanical Engineers, on Benson's boiler, when worked with salt water, at high pressures it would be found there was no incrustation at all, which was attributed to the rapid circulation of the water.

Mr. R. G. M. Smith cited an instance of a well producing almost pure water. It contained an alkali, but no lime—with which a boiler had been supplied for twenty-three years, without any incrustation being formed, or any apparent wear having taken place. The boiler was cleaned by simply brushing it with a broom. But another well was sunk, within half a mile, that contained so much carbonate of lime that an incrustation was formed in a few weeks. The wells were sunk through the London clay into the chalk.

Mr. Hendry had noticed in Wales, especially in Swansea, that the water was impregnated with copper, and, consequently, the wrought-iron pipes would not stand. He had seen a very simple remedy for preventing incrustation, viz., placing in the boiler logs of oak, about two feet long, with the bark on, which kept the boiler perfectly clean. He had never heard of any good result being effected by the use of the different fluids sold for preventing incrustation.

Mr. R. M. Christie stated that great damage might be done to boilers by the disposition of the water feed pipe, and the steam supply, and blow off pipes. By placing the water feed over the furnace, a deposit would undoubtedly be much sooner formed at the worst possible position, to the certain injury of the boiler. He considered the supply of water should be introduced at the back of the boiler, and the blow off pipe placed in the front, and thereby obtain proper circulation. He objected to the use of acids, as serious damage to the iron might be the result.

Mr. B. D. Kershaw said one of the London water companies put pieces of oak into their boilers, which had the effect of reducing the carbonate of lime to a kind of sludge, which fell to the bottom, and the deposit found was very small. This plan had been pursued for many years with perfect success.

Mr. Howson attributed the success in the use of oak logs due to the gallic acid, which covered the iron with a sort of black slime.

Mr. F. C. Reynolds thought the remedy for the prevention of deposit in boilers might be classed under three heads: First, to prevent a general hard deposit being caked over the surface of the boiler, which might frequently be done by the introduction of some chemical substance; Secondly, the incrustation being prevented, to remove the deposit from time to time; a rapid circulation would be beneficial in preventing the deposited matters becoming caked hard, and they could then be blown off; and, Thirdly, to use pure water, when it might be reasonably inferred that the deposit would be almost, if not entirely, prevented.

Mr. Riley, in answer to the points raised during the discussion, said that the boiler was cleared out every six weeks, and that he quite agreed that a good circulation of the water was most advantageous. The ingredients in most waters are the same, and differ only in their relative proportions. The principal constituents were the carbonate and sulphate of lime. Mahogany sawdust had been employed with advantage to prevent incrustations in boilers, and it acted in two ways; first, mechanically by forming so many small points for the carbonate and sulphate of lime to be deposited on; secondly, he thought that there was some peculiar action of the extractive matter in the wood. This would apply more particularly to oak, especially when green, in which state it was usually used.

Chloride of ammonium (sal ammoniac) had been suggested and used. This salt would convert the lime salts into soluble compounds, viz., sulphate and carbonate of ammonia and chloride of calcium; but its application had not been very successful practically, as it was found the sal ammoniac and ammoniacal salts acted on the brass work. As to the use of hydrochloric acid, he quite agreed that the remedy was worse than the disease, as it would require to be used with excessive caution, the composition of the water from heavy rains, &c., not being always the same.

The Chairman in conclusion remarked, that in North Wales he had seen water perfectly green used in boilers, and oak sawdust was used in considerable quantities. Water too pure, however, was not, as a rule, to be preferred to water of an ordinary description. This he had seen instanced in the neighbourhood of Epsom, where water was difficult to be obtained, when rain water was used. These boilers were much more troublesome to keep clean than boilers supplied with water by the New River Company or

the East London Water Works Company. He considered the use of corrugated plates an excellent plan, as it carried out the principle of expansion and contraction. They were used some years ago in marine boilers. As a general rule he thought locomotive boilers less subject to incrustation than others, which might be attributed to the different qualities of water taken in during the journeys.

March 3rd, 1862.

E. RILEY IN THE CHAIR.

ON TRUSSED BEAMS.

By W. PARSEY.

The construction of beams, girders, principals of roofs, arches, and other means of carrying roads, railways, canals, or other communications, over rivers and valleys, or for passing over or under roads, and for supporting loads under various circumstances, is a subject that requires a considerable amount of study by the engineer.

It is intended to confine the subject of the present paper to *trussed beams* with straight members, as it is considered that the introduction of the *arch*, either supported by bracing or acting unassisted, should form the subject of an independent inquiry. The first object is to inquire into the fundamental principles, and then extend them, from the simplest form of trussed beam, to the more complicated trussed or lattice girder, and then to compare them with the solid web, box, or tube girder, as regards efficiency to carry the load, durability, facility of erection and repair, weight, and cost.

The comparative efficiency of two beams may be measured by the working strain put upon the parts, and also by the amount of deflection with the required load. With box, plate, and trussed girders, the deflection varies as the square of the depth; so that of two girders with the same working strain in the top and bottom flanges, one may be much stiffer than the other if the depth is greater. The deflection is not, therefore, a measure of the strength of a girder, but it is a quality worth retaining, unless some other consideration should outweigh it.

Durability should not be lost sight of in any design, and in wrought-iron girders, and roof principals, should be well considered. The great enemies to iron are oxidation and crystallization, and in many cases they are doing their work of destruction unnoticed.

There are many instances of iron plate and bars only $\frac{1}{4}$ or $\frac{3}{8}$ in. thick left to rust, so that the surfaces are gradually being eaten away; and

FIG 1^A

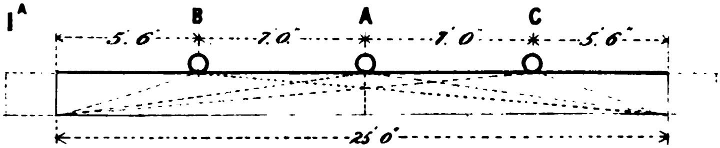


FIG 1

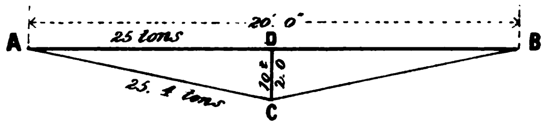


FIG 2

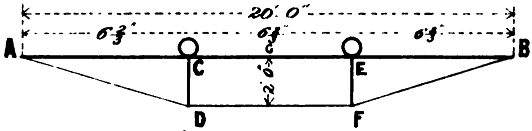


FIG 3

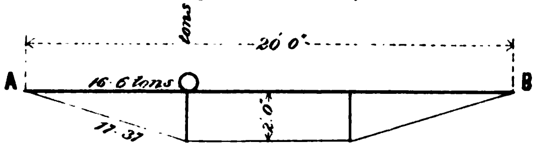


FIG 4

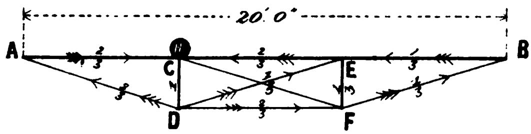


FIG 5

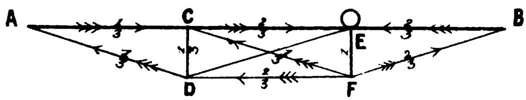
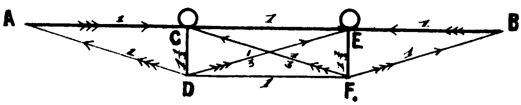
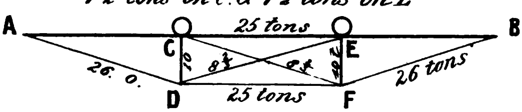


FIG 6



7½ tons on C & 7½ tons on E

FIG 7



although the parts are doubtless thicker than absolutely necessary for strength, still there must be a limit, which may be reached some day, and lead to accident.

But if the work be well maintained, and some of the parts cannot be got at to be protected by paint or other means, it may be exposed to the same evils which would arise from negligence.

The first consideration, after determining the general character of a beam or truss, is the *amount of load* which it will have to sustain, and the way it will act on the parts. In the case of cast-iron beams or web plate girders of small span, it is customary, and sometimes sufficient, to calculate the sectional area of the top and bottom flanges at the centre, for a load supposed to be equally distributed over the length of the span. The section of the top and bottom flanges are proportioned to the strain, according to the material of which the girder is to be constructed; and generally either the depth or area of the flanges are reduced from the centre towards the abutments, to economise material as far as practicable.

But a careful investigation of the effects of a rolling load on a girder will show that it is necessary to provide for its effect much sooner than was formerly expected, as will be seen by reference to Fig. 1 A, which shows the strains for an ordinary girder 25 ft. span. The strain at the centre, due to an equally distributed load of ¾ ton per foot run, would be 33·48 tons, and at B, and C, it would be 23 tons.

If the same girder were loaded at three points, A, B, C, which might be the position of the wheels of a large locomotive engine, the strains would be 40·2 tons at centre and 28·24 tons at B or C.

The assumed load of ¾ ton per foot distributed is equal to 9⅜ tons at centre, and was considered to be sufficient for any rolling load that might come on the girder; but the load of 6 tons at the points, A, B, C, is possible by the largest class of express and tank engines; and although the sum of the weights is less than the distributed load by ¾ ton, the strains on the girder are much greater.

If the effect of a distributed load be taken as the standard of comparison for the strength of a girder, it will not matter of what form the trussing may be, for the total effect of the leverage due to the weight will be the same for the same span and mean depth of truss.

Fig. 1, represents a simple trussed beam; and the relative length of the

lines D C, A D, A G, respectively represent the proportion which a quarter of the distributed load, the horizontal and diagonal strains bear to each other, so that if A B, be 20ft., and 20 tons is distributed, then by the formula,

$$\frac{\frac{1}{4}\,W.\ \frac{1}{2}\,L}{D.} = \frac{W.}{8}\frac{L.}{D.} = 25 \text{ tons horizontal strain at centre.}$$

If the top member, A B, be trussed, as shown by Fig. 2, then it is evident that for the same span and depth the horizontal strains will be exactly the same as in Fig. 1, for the weight is acting with precisely the same leverage.

But if the distributed load be collected at the points C and E through which the load must be transmitted to the tension bars A, D, F, B, then half the distributed load, or a quarter on C and a quarter on E, will not produce the same strain in the top and bottom members as before, because they are acting with less leverage; and an assumed load must be taken to produce the same horizontal strains as an equally distributed load.

The point C is two-thirds of the distance, A G; and, therefore, if a weight in an inverse ratio to the leverage be supposed to be acting, the horizontal strains will be the same as before; therefore 7½ tons at C, and 7½ tons at E, will be the required weights, and the total strains may be collected by first supposing the weight on C and then on E (See Fig. 3.)

First let the weight, 7½ tons, be on C, then 5 tons will be resting on A, and 2½ tons on B, and the horizontal strain may be obtained by either multiplying two-thirds of the weight by one-third of the length, or one-third of the weight by two-thirds of the length, and dividing by the depth.

The effect of the weight resting on B will produce a horizontal strain equal to 8·33 tons in the contrary direction from B to E, and a similar strain will be produced by the stiffness of the bearer A B towards C, and so equilibriate the forces. If the other weight (7½ tons) be now placed on E, contrary strains will be produced, and the total horizontal strain of 25 tons produced as before.

Fig. 4 is a similar truss to Fig. 2, with the bars in the centre bay added, by which the strains will be conveyed uniformly to the top and bottom members, and will support a load at either of the points C or E without any tendency to alter its form, while the load is within the amount calculated for.

The strains may be traced by referring to Figs. 4, 5, 6, and 7, which

show the same truss with different conditions of load. In Fig. 4, the load (1) is on C; then the strains are, as expressed, two-thirds being in A C, A D, and one-third in B E, B F, and D E.

The load on E produces similar strains, as shown on Fig. 5, and when both loads are on the strains will be as on Fig. 6. Fig. 7 gives the strains in tons for 20 ton distributed load.

The forces as expressed in terms of unity require to be reduced, so that if the weight is $7\frac{1}{2}$ tons as before the $\frac{7\frac{1}{2} \times 6\frac{2}{3}}{2} = 25$ tons horizontal, and the tenison in the diagonal will be in proportion to its length, or

$\sqrt{\left(6\frac{2}{3}\right)^2 + \left(2\right)^2} = 6.95$ feet, and $\frac{7{\cdot}5 \times 6{\cdot}95}{2} = 26{,}0625$ tons. The strain on D E, or C F $= 8{\cdot}687$ tons.

By the reasoning used for Figs. 4, 5, 6, a system is obtained for finding the strains upon any system of trussing by extending the operations, which become more complicated as the number of parts are increased, but the same general principles only need be employed.

Before proceeding with an example applied to a large girder it will be as well to see how far these principles can be applied to roof principals. Fig 8, is the simplest form of principal, and may be compared with Fig. 1, which is the same form inverted, and if the span and weight be the same the strains will be the similar, excepting that compression will be replaced by tension and *vice versa.*

This construction is limited by the length of the rafter A C, C B, which must be stiff enough as a beam to bear the weight of the roofing and the assumed load.

In roof principals lightness and stiffness are very important features, and to make the rafters of any considerable length without support would necessitate their being made heavy, and in fact would be opposed to the principle intended to be carried out, there is not however any particular length to be assigned at which the rafters should be supported by struts, because the span of the principal and other considerations must be taken into account, but in almost all cases where an iron principal is employed the span is such as to require some trussing to the rafter.

In the foregoing examples of trussed beams; after tracing the strains

through the different members the same horizontal strain has been obtained for similar spans, depths, and loads, although the arrangement of the struts, and ties are different; but in roof principals of the form shown by Fig. 11 the strains increase in the rafter and tie rod from the centre towards the ends or point of support.

The force of a strong gale is about 40 lbs. to the superficial foot; if therefore that force is supposed to act horizontally on a roof sloping 2 to 1, it would be equal to 20 lbs. distributed on half the roof. In moderate spans the weight of the roofing is about 12 or 15 lbs. per superficial foot; so that the weight of 40 lbs., which is generally adopted, is sufficient to provide for either force that may be acting.

In this country we are seldom visited with a very considerable depth of snow, and the effect of wind is perhaps the greatest force that will have to be resisted.

There are however, various circumstances which must be considered according to the special conditions of each case. If a roof were required to be placed in open country, and much exposed, it would be as well to provide for unequal strain, and it should not be forgotten that in some instances the wind will lift instead of bear down.

To return to the subject of strains:—let Fig. 9 be the principal of a roof 40 ft. span and 10 ft. apart, then 40 ft. × 40 lbs. × 10 ft. = 16,000 lbs. for the distributed load on one principal; the distributed weight over E, C, F, may be treated separately from that on A E, and F B, and it will be just the same in effect as if E C, and C F, were two beams, each of 4,000 lbs. weight, leaning against each other. The weight on A E, would act with a leverage, which will be transmitted through the strut E D, and the king rod C D, and produces a strain equal to half that due to the upper part C E, therefore the whole strain from C to E, will be 8,944 lbs., from E to A, 13,440, in the strut E D, 4,472, and in the tie rod 12,000.

It will be observed that these strains are multiples of 4,000, with the addition for the angle in the inclined bars.

The strain in the upper part of the rafter is in all trusses of this form equal to the effect of an equally distributed load upon a truss of the greatest depth, as C D, and an increase is due to each strut upon the tie rod and rafter in proportion to the weight upon it.

FIG 8

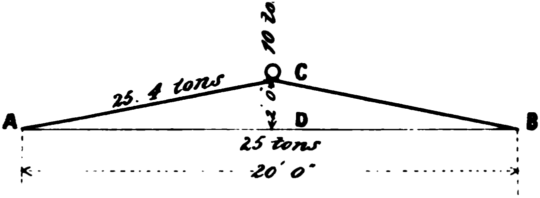


FIG 10

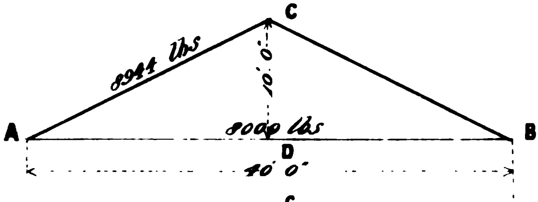


FIG 9

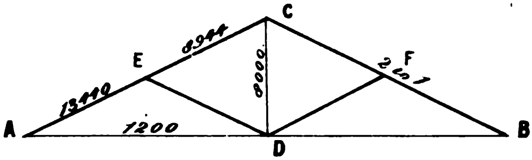


FIG 12

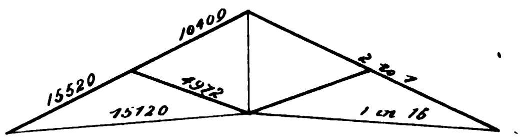


FIG 11

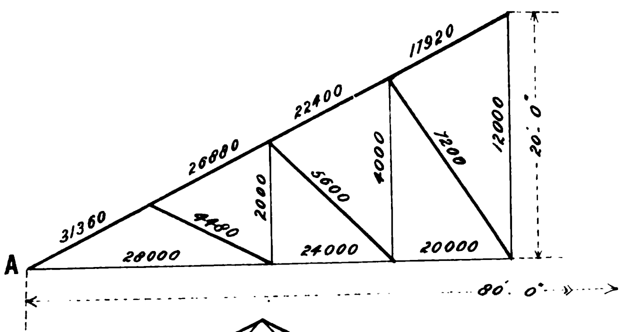


FIG 13

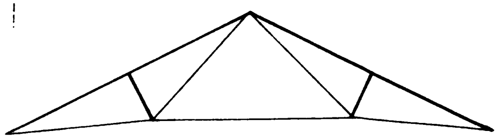
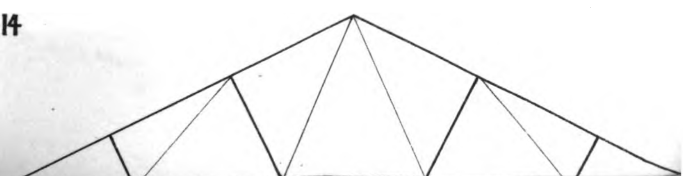


FIG 14



The above example contains the general principle for finding the strains upon any similar truss, whether of two triangles as in Fig. 9, or of more as Fig. 11, the same system only requires to be carried out; it will be easy to perceive that the strains follow the same law, the strain at the top of the rafter is equal to the effect of half the distributed load; in this example the span is assumed to be 80 ft., or double the former, and the load to be 32,000 lbs. The additional strain due to the weight acting through the struts is commenced at A, and the strain acting down the first strut is added to the weight on the rafter above, and again carried down the second strut, that is again added to the weight on the third strut, and finally comes to the king rod.

Fig. 10 is given to show the comparative strains in two trusses, one with and the other without a strut, and it will be observed that the strains are less than for the similar truss, Fig 9.

The strain in C E, is equal to the strain in C A, and the strain in A E, is more by one-third than in C E, but the rafter C A, Fig. 10, is twice the length of A E, without support, and as it has to resist compression, it is weaker nearly in proportion to the square of the length, therefore it would require to be at least four times the sectional area to bear the same force unsupported. This reasoning is only approximate, for the laws regulating the strength of columns is very difficult to apply to irregular forms, and there is no practical rule by which the exact strength of a piece of L or T iron can be ascertained; it is well known that they are not the best forms to resist compression, but the various connections are the most important consideration under the circumstances. There is, however, a saving in the quantity of metal by applying the strut E D, although the tie rod has to be increased one-half, and the strut E D, added.

In the foregoing examples the tie rods have been horizontal, but they are generally cambered more or less, and the effect upon the stains is very marked. Fig. 12 is similar to Fig. 9, except the camber which is 1–30th of the span, so that the depth of the truss is reduced 1 ft. 4 in, and all the strains are increased in a ratio due to the increased depth of the truss. The length of the main tie rod is increased, but the struts are shortened, and this is important as they require to be trussed when of considerable length.

Fig. 13 is a very good arrangement for small spans. The rafters are supported at the centre by a short strut, and all the long lines are in tension.

Fig. 14 is a diagram of a truss similar in principle to those in the roof of the Victoria Station, Pimlico; it is preferable to the arrangement Fig. 11; the struts are at right angles to the rafter and are, therefore, the shortest possible.

It is not, therefore, surprising that engineers have directed their attention to the principles of trussing, in the construction of girders for carrying railways or roads over large spans. Solid webbed girders can be built as cheaply, up to about 60 ft. span, as trussed or lattice girders, for although the latter could be made lighter, the additional cost per ton in construction would make them at least equal in cost, from 60 ft. to 100 ft., and under some circumstances 150 ft. span; the relative advantages of one plan or the other fluctuates.

There can be no doubt of the solidity and permanence of the solid web or bore girder, they are structures in which implicit confidence may be placed; if the iron is good and the punching and riveting carefully done, and as these are matters that can be controlled and ascertained, there can be no doubt about the attainment of the object by them, but as the span increases the weight of the girders increase nearly in proportion to the square of the span, and, therefore, the structure is gradually approaching a weight by which it will be destroyed without any load, so that it becomes a matter of greater consequence, every foot that the span is increased, to reduce the weight of the girder itself.

The strength of wrought-iron girders increases in proportion to the depth, so that a beam twice the depth of another is twice as strong, with the same sectional area of top and bottom flanges, and all that has to be added is the web or vertical connection between them; but in the solid webbed girder it is a considerable part of the weight, generally exceeding, with the necessary stiffening, one-third of the whole.

In the Britannia tube, the weight of the top is 450 tons, the bottom 436 tons, the sides 398 tons, or rather less than one-third; but this is less than can be arranged in ordinary girders, because the top and bottom being formed with cells across the line, and connected to the sides, it is a stiffer form laterally than when two separate girders are employed.

To double the depth of such girders necessitates an increase of something more than one-third of the original weight, and this object can be attained more economically by trussing of various forms, of which the lattice,

Warren, and girders of the Boyne Viaduct and Charing Cross Bridge form examples.

The lattice girder is the first step from the solid web; for if a number of lozenge-shaped holes were cut out of the web, leaving a series of bars crossing each other, the lattice girder would be practically given.

In the Warren girder, every member has a certain duty, and that only, to perform, excepting the diagonals at the centre, which have to bear tension and compression with unequal loading; but the amount is so small that it involves no difficulty. There is some advantage in these properties, because every part can be designed of a form best suited to its work, and the strains can be calculated to the greatest nicety for permanent and rolling loads.

It is usual to assume the load to be collected at the angles formed by the diagonals, and the amount equal to a distributed load between the points.

Fig. 15 shows a Warren girder 100 feet span, and 10 feet deep. It is made with only five triangles on the upper line for comparison with Figs. 16, 17 and 18. If one-fifth of the load (10 tons) is supposed to be acting on A, B, C, and D, its effect will be the same as if it was distributed half way on each side of the point; therefore, the effect of each supposed weight can be taken singly, and the sum of all the strains in the diagonals, resolved into horizontal strains, will be the total at the centre, on top and bottom members of the truss.

It will be observed that there is no strain with an equally distributed load on the centre diagonals, and also that the sum of the strains due to loads of ten tons on A, B, C, and D, is not equal to the effect of the equally distributed load; that is, $\frac{50 \text{ tons} \times 100 \text{ feet}}{8 \times 10} = 62{\cdot}5$ tons horizontal strain at centre; but the sum of the strains from weights on A, B, C, and D, is only sixty tons. This was to be expected, as each of the ten ton weights are acting at their centre of gravity, and the weight of half the bay next the abutments has not been taken into account. If the effect of that weight is put on the next pin, it will make up $62\frac{1}{2}$ tons.

The effect of a load brought on to the two pins on either side of the centre only, would cause a strain of three-fifths of ten tons in the centre diagonals, which resolved amount to 8·484 tons; but in all the other bars, the strain would be less than with a full load.

It has been thought by some that the weight on the half of the last bay does not act on the truss, but rests on the pin, and therefore should not be taken into account; but it is evident, on reflection, that all the load between the points of support is acting.

The strains upon such girders as those of the Boyne Viaduct and Charing Cross Bridge are very similar to the last example, as will be seen by reference to Figs. 16, 17, and 18, which show a girder 100ft. span, 10ft. deep, with diagonals crossing each other at right angles. The strain due to 100 tons distributed on such a girder would be 125 tons horizontal at centre, and the sum of the strains in the diagonals resolved is exactly equal. This girder might be divided into two, Figs. 17 and 18, each capable of supporting 50 tons distributed, and the strains in the diagonals would be the same as the similar bars in Fig. 16.

This construction (Fig 16) is preferable to the Warren for large spans, as the length of the struts is reduced by crossing the diagonal ties, and being connected to them. The size of the connecting pins or other connections between the top, bottom, and diagonals is also reduced, which is a great advantage in practice.

Girders of this class can be constructed 1-10th of the span deep with about one-third of the weight in the vertical web, and are, therefore, much more economical in weight than solid web or tube girders; the workmanship and construction requires more care and accuracy, and the cost per ton is, therefore, somewhat greater; but for transport and erection abroad, where the cost of freight and sending skilled artisans to erect has to be added, the advantage will be with the trussed girder.

There has been reluctance on the part of some engineers to adopt trussed girders, and there are many, at the present time, who would not employ them; they are pointed at as having failed in some cases and been unsatisfactory in others; but it must not be forgotten that many very satisfactory examples exist, and that an error in the proportion of the parts, which are all dependant on each other soon deranges them. The connecting pins in many girders have been made too small; in some cases so as to have 10 tons per square inch on the bearing surface, which is nearly sufficient to indent the pin and upset the metal in the tension-bar. But if this does not actually take place, it is much too great a weight for parts that are frequently in motion.

FIG 16

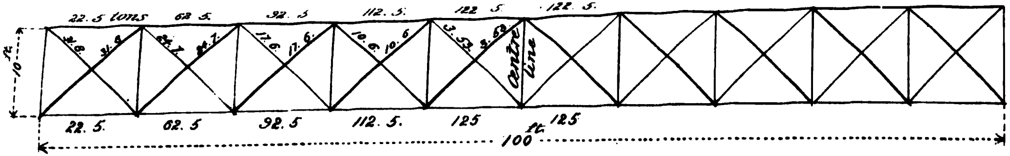


FIG 17

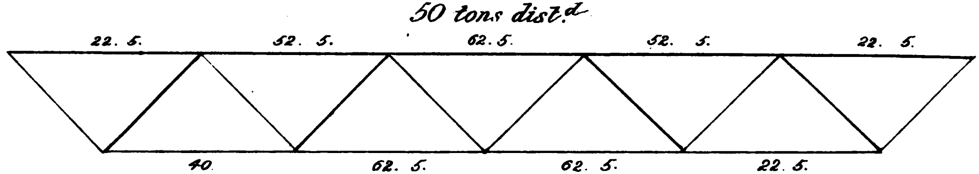


FIG 18

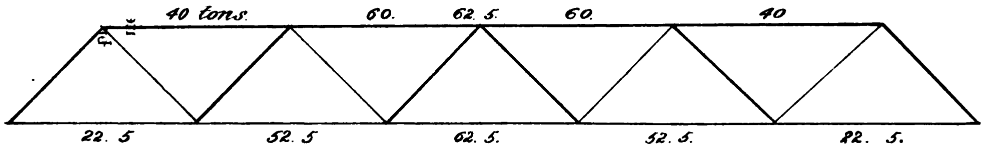
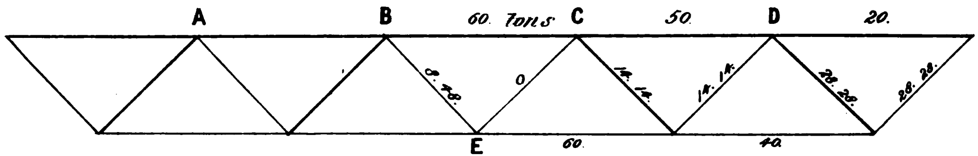


FIG 15



Strains in B.E or C.E with 10 tons on A & B

Strains with loads on A B C & D.

There are many examples of these girders lately constructed which have the advantage of being properly proportioned and well made, and a short time will set the question of their efficacy at rest.

DISCUSSION.

Mr. H. P. Stephenson entered into the comparative merits of the Warren, the lattice, and the plate girder. He considered the Warren girder an admirable form for easy carriage and rapid construction, but as the whole of the strength depended upon the strength of every single bar, he objected to the principle. The struts of the bridge in Joiner-street, erected on this principle, and which failed, were of cast iron. The large railway bridge at Newark Dyke was also on this principle, the struts were also of cast iron, but the whole of the bridges lately constructed were of wrought-iron, which was a great improvement. He considered the lattice girder an improvement upon the Warren, because in that principle dependence was not so much placed upon single bars or single joints, but, in his opinion, the plate girder was preferable to either. Plate girders did not require such skilful workmen, and though they were more objectional in the way of carriage, yet he thought their greater amount of stiffness more than compensated for the cost of any extra transport that might be incurred.

Mr. C. J. Light, in referring to some large Warren girders in course of construction at Messrs. Westwood, Baillie & Campbell's works, for the Great Indian Peninsula Railway, said that the connecting pins were made of ordinary iron, steeled by Dodd's patent process to a depth of about 1–16th of an inch on the finished pin, which gave the surface the necessary hardness for bearing the tension of the bars. It is a practical fact that there is no difficulty in obtaining for any number of bars, whether links or struts, an accuracy of 1–100ths part of an inch in the distance between the holes.

Mr. Carrington said a lattice girder was a compound Warren girder, in which the diagonals cross each other, while in the Warren girder they did not. He could not understand why a royalty should be paid on a girder with a single set of diagonals, any more than on a girder in which the diagonals cross each other.

Mr. Ordish referred to the Charing Cross Bridge as being an excellent example of a Braced girder bridge.

Mr. Parsey, in reply, stated he was not an advocate for using cast iron

for struts in these bridges, and if it was used it would be of the utmost importance to test them all. It was the opinion of a great many engineers, and among them the late Mr. Robert Stephenson, that a wrought iron plate girder bridge was preferable to a trussed bridge, but he had had considerable experience with Warren girder bridges, and did not find any difference in the results obtained. He had seen a Warren girder bridge of 142 ft. span, tested with a distributed load of one ton per ft. run on each girder, which deflected 2½ in. With reference to the working strain put upon the parts of Warren girders, it is usual to adopt about the same amount as in ordinary plate girders, that being 4 and 5 tons for compression and tension respectively. The necessary accuracy in the workmanship, though apparently difficult to obtain, was, with the perfect machinery now at the engineer's disposal, easily effected, for the holes in a number of pins or struts could be bored to within 1–100th of an inch, or less, of each other.

April 7th, 1862.

E. RILEY IN THE CHAIR.

ON TRUSSED BEAMS.

By W. PARSEY.

ADJOURNED DISCUSSION.

Mr. Parsey said during the discussion on his paper at the previous meeting some points were raised as to the comparative weights of the different girders; he then gave a few examples so as to afford some comparison between the absolute weight of the two girders, and also the deflection which would be due to them.

For comparison he had taken a web plate girder of 60 feet long, and weighing eight tons; the top, bottom, and middle of the flange weighed respectively as near as possible one-third of the whole weight. It was constructed for one of the railways in India, and to bear a lighter load than the other girder. The ratio of the weight in the Warren girder was different to what it was in the plate girder, the top flange had generally been made heavier in proportion to the other parts to provide a certain amount of stability; in another case he had compared a Warren girder, of 142 feet span, weighing 35 tons, and a plate girder of the same span

weighing 42 tons—thus it would seem that the Warren girder was both lighter and cheaper.

The calculated deflection of the Warren girder is $1\frac{3}{10}$ inch, and the plate girder $1\frac{27}{100}$ inch. The actual deflection of about 16 Warren girders was $1\frac{42}{100}$ inch; this favourable result was due to the accuracy of the workmanship, and to the area of the bearing surfaces and connections having been very much increased.

Mr. Rumble exhibited diagrams of the Crumlin Viaduct, which was on a curve of 20 chains radius, and on an incline of 1 in 230, nearly 200 feet high, and about one-third of a mile in length, its cost being about £47,000. The piers were composed of 14 cast-iron columns, 17 feet long, the metal three-quarters of an inch thick. The girders were tested at Crumlin, with 230 tons on the centre, the deflection was nearly two inches, after the girder had taken its own weight.

Mr. C. J. Light exhibited a diagram of the tests of a Warren girder bridge, 142 feet span. The chief fault of this bridge, and that seemed to be unavoidable, from the rails being carried over the centre of the main girders, was its narrowness.

One of the links, 15 ft. 9 in. long, when tested, stretched 15 inches, and then the hydraulic came home, and consequently they could go no further. The pressure was then 21 tons to the square inch, and there was not the slightest mark of strain in the bar. There was a very remarkable action at one particular point observed in testing these links. When at a strain of between 12 and 14 tons to the inch a sudden jump took place in the permanent set; experiments had been very carefully taken, and it was observed that up to between 12 and 14 tons, the permanent set was very trifling, and the extension comparatively small, but the moment it passed that point the extension became considerable, as did also the permanent set.

Mr. Perry F. Nursey inquired whether the links, when released returned to their original length, or how far they returned.

Mr. Parsey said it had been found that when a bar under tension had a certain amount of elasticity before it took a permanent set, that with an additional strain of the same amount it had the same amount of elasticity as previous to taking permanent set.

With regard to the extension of the iron, and particularly proving the

rules given by Mr. Hodgkinson and others, they had always found that the extension of the iron was nearly equal, with equal additions of weight up to the point where it took its permanent set. It appeared doubtful whether there was any permanent set upon iron up to 10 tons to the inch. Those qualities of iron that showed permanent set easily, were not always the worst. Mr. Tredgold had given the point at which permanent set takes place, when the iron had taken an extension of 1–1400th part of its length. This agreed with his experience, as he had tested a bar 10 feet long with a strain of 10 tons per inch, which gave an extension of 1–10th of an inch, equal to 1–1200th part of its length. The bars always returned back again without perceptible extension, and from that point began to extend in a greater degree, and continued to increase up to its breaking point.

Mr. Olrick said, that after a certain point the crystallization of the iron was spoiled, but this point was very difficult to find, unless the iron was cut to pieces and examined by means of a microscope, and a number of experiments made.

The Chairman asked whether it was the practice to test all the bars to find the permanent set.

Mr. C. J. Light stated the whole of the bars were tested with about 10 tons to the square inch.

The Chairman remarked that if the bars were tested with more than 10 tons it would be likely to deteriorate the iron.

Mr. Parsey had frequently tested the bars a second time and they did not appear to be injured; they always took up the strain again without extending so much as they did in the first instance until the greatest first strain was reached, therefore, as far as the strength of the bar was concerned, it was stronger than before. With reference to the transverse strain, Mr. Edwin Clark tested some 1¼ in. square bars, by first bending some of them and straining them again, found them stronger than the bars that had not been bent.

Mr. P. F. Nursey inquired at what point in the links the fracture took place in those that were broken.

Mr. Parsey, in reply, said in most cases the bars broke through the ends, either behind the pin hole or across the head at the pin holes. In most bars the proportion of the bearing surface on the pin to the body of the bar is as

2 to 3, so that if there were 10 tons to the inch upon the body of the bar there would be 15 tons on the back of the pin hole, which would upset the metal and cause a certain amount of motion, and the surface of the pin would begin to act as a wedge, and split the bar directly behind the pin hole; that was the reason why the heads of the links were made with more metal across and behind the pin holes. With regard to the wear and tear of the pins connecting the links in a Warren girder, he thought that as the surfaces were always in contact it would be very little. The amount of friction by the deflection of the girders would be very small.

The Chairman in closing the discussion, observed that the subject was of very great importance, and he thought much valuable information had been elicited.

May 12*th*, 1862.

E. RILEY in the Chair.

ON THE USE OF COAL IN FURNACES WITHOUT SMOKE.

By Chas. F. T. Young.

From the first employment of coal in open or closed furnaces we find the desirability of abating the nuisance arising therefrom fully admitted, and also that attempts were and are being made to get over this unpleasant and unsightly nuisance.

Twenty years ago a writer said on this subject: "The smoke arising from the furnaces employed at factories has, within the last twenty or thirty years, been felt as a great nuisance in most manufacturing towns, polluting as it does the pure air of heaven, and injuring every exposed object within the range of its influence. Those employing furnaces having also become generally aware that if either *less* of it were generated, or if when generated it could be consumed, there would be a great saving in the expense of raising steam."

The immense increase in the use of coal is continually adding to, instead of decreasing the dense volumes of smoke which meet our eye in nearly every direction, more especially in the manufacturing districts, and as a rule, it may be said that but little success attends the attempts made to diminish the evil, or at least if this is not the case, that little employment is given to those methods by which the nuisance might be reduced.

The nuisance caused by the falling of the soot or blacks, and of which, by the way, we have a tolerable allowance in London, has increased of late years to such an extent in Leeds, that many situations used by the inhabitants for drying linen in the open air have been obliged to be given up, and the fact that smoke and soot loading the atmosphere, filling the eyes and mouths of the passers by, and spoiling their clothes, are intolerable nuisances, is too plain to need any further proof.

The influence of the atmosphere of London was felt for miles around, though at present its effects are much diminished, and all who live in the neighbourhood of a smoky manufactory are well aware that the more delicate plants grow with difficulty in such situations or perish entirely. The effect of a single factory chimney has been traced, by the grass in the direction of the prevailing winds being destroyed and nothing remaining but rank weeds of a few species capable of resisting the smoke.

The smoke nuisance, it may be remarked, has even its supporters, for it has been urged by persons of a "smoky" tendency, that the healthiness of London is in a great measure due to the large quantity of carbon with which the atmosphere is constantly charged, and which absorbs the poisonous exhalations of the sewers and other fetid matter. No doubt this may have a certain amount of truth in it, because carbon or charcoal is well known to be a powerful disinfectant, but one would think that some more pleasant way of getting rid of the effluvia, which is said to be destroyed by the carbon, might be arranged, so that the perpetuation of this nuisance need not be sought on sanitary grounds.

The worst portion of smoke is the superfluous carbon which is left unburnt, when either sufficient atmospheric air is not present, or the temperature is not sufficiently high for perfect combustion of the varieties of carburetted hydrogen, and the vapour of coal tar, which are disengaged from heated coal. Under either of these circumstances the hydrogen inflames, while the carbon is left to be carried forward by the draught of the chimney, poured out of its mouth, and ultimately to fall to the ground, and form the nuisance so loudly and so justly complained of, and of which we have such an excellent example in London.

It should always be remembered that in burning coal it is needful to introduce air in sufficient quantity to maintain a sufficiently high temperature in the furnace, and to so distribute it amongst the solid and the gaseous portions of the fuel to effect that thorough mixture of the air and the gases, whereby alone their perfect combustion can be ensured, and the formation of smoke prevented.

At every charge of fresh coal on the fire, the *first* product is not *smoke* in the strict sense of the word, but a very large body of crude impure coal gas, or rather coal in a minute state of diffusion or

disintegration; and this is in either greater or less quantity, and of longer duration, according as the furnace is more or less free in obtaining the supply of air needed to obtain a perfect combustion.

It should be borne in mind that there is not much difficulty in getting a large quantity of air into a furnace; opening the furnace door for example would let in air enough, but then there is the disadvantage of *cooling* the furnace and *lowering* the steam, from the air introducing itself "in a lump" and not becoming intimately and rapidly mixed with the products of combustion.

It is further necessary that the due proportion of atmospheric air should be intimately mixed with the combustible gases before or during exposure to the requisite temperature; otherwise however much may be introduced, it cannot be said to be present availably for the intended purpose. In ordinary furnaces at the period when smoke is most abundant—that is soon after the coals are thrown on—both of these conditions are wanting; too little air is present and the temperature is too low at the surface of the fresh fuel for perfect combustion, and the entrance of air through the bars, which would to a certain extent assist in promoting combustion, is diminished, by the coals just thrown on having closed as it were the apertures through which it could enter.

Theoretically speaking, if a furnace could be so constructed, that the proper amount of air could be constantly admitted in its proper place, at the various states of the fire, from its *green* state after a heavy charge of coal, to its bright and clear state, and *no* more than is actually required at each stage, no smoke would ever be seen; but as in practice this for various reasons cannot be carried out, recourse is obliged to be had to various plans as additions, by means of which this perfection is sought to be attained, and the intolerable nuisance of clouds of black smoke diminished.

The late Dr. Dalton has shewn by his interesting experiments, that for perfect diffusion of the air amongst the gases *time* is required, but the construction and working of ordinary furnaces will not admit of this, therefore, in order to get over this difficulty, we have to apply some mechanical arrangement. Dr. Ure says he found by experiments made with Dr. Wollaston's Differential Barometer, in several factories where both high and low pressure steam was employed, "that the

aerial products of combustion from the boiler furnaces flew off with a velocity of fully 36 feet per second; a rate so rapid as to preclude the possibility of the hydrogenated gases from the ignited coals becoming so duly blended with the atmospheric oxygen as to be burned."

It will be evident therefore that there is something more needed to prevent smoke, and thereby promote economy in fuel, than the mere admission of air into the furnace. It has just been shewn that we may have *enough* air, but that from applying it in a wrong manner, though we may to a certain extent diminish the smoke we also diminish the steam, a process which few of the boilers at present in use can permit without seriously impairing the working of the engine. If we take the open end of a gas pipe and burn the gas issuing therefrom, we have a great amount of smoke and but little heat; pass the gas through a common argand burner, and we have an intensely hot, smokeless, flame, By this we see that the numerous small holes with which the argand burner is provided, afford that more rapid and perfect diffusion of the gas amongst the air required for its combustion than is afforded by the large bore of the tube, which suffers the gas to escape in a lump or solid mass, unmixed with the amount of air required for its perfect combustion.

From this we learn that instead of admitting the amount of air required for the perfect combustion or complete utilisation of the fuel put into the furnace, it should be so admitted that it becomes thoroughly and quickly intermixed with the hot gases whilst still in the hottest part of the furnace, if it be properly managed, we evidently obtain thereby the rapid diffusion and complete mixture required for perfect combustion.

It has long been a favourite idea, which is no doubt perfectly correct in *theory*, only we don't get it in practice, that *if* we can have sufficient furnace space by the proper setting of the boiler; that *if* we can secure the proper amount of air during the process of combustion; that *if* we can keep the engine at work by careful and moderate firing; and that *if* we can secure proper care and attention on the part of the firemen, no smoke would be produced, and that therefore no apparatus for preventing smoke would be needed.

All this we shall readily admit, but then to *do* this requires what

we have *never yet seen*, viz., a *perfect* furnace, *perfect* attention on the part of the men, and *perfection* all over; conditions, which in nine hundred and ninety-nine cases out of a thousand, it is utterly impossible to fulfil under the circumstances in which most of our steam boilers are employed. The continually increasing demand for increased power from most engines, requires them to be worked, and the fires to be urged beyond their usual or original capabilities; and, consequently, hard firing, increased consumption of fuel, increased smoke, increased wear and tear, and increased neglect of smoke abatement, are the inevitable results of such a system; and must sooner or later lead to some more powerful and increased control being exercised over the owners of steam power.

The late Dr. Andrew Ure remarked, that "nothing places in a clearer light the heedlessness of mankind to the most instructive lessons, than their neglecting to perceive the difficulty of duly intermingling air with inflammable vapours for the purpose of their combustion, as exhibited in the every day occurrence of the flame of a tallow candle or common oil lamp; for though this flame be in contact externally with a current of air created by itself, yet a large portion of the tallow and oil passes off unconsumed with a great loss of the light and heat which they are capable of producing. It is well known that elastic fluids of different densities, such as air and carburetted hydrogen intermingle very slowly, but when the air becomes considerably carbonated, as it does in passing through the grate, and consequently heavier, it will not incorporate at all with the lighter combustible gases above it, in the short interval of the aërial transit through the furnace and flues. Thus there can be no more combustion amidst these gases and vapours than in the axis of a tallow candle. The first operation which coals undergo when thrown into a common furnace, is distillation attended with a great absorption of heat, and may be compared to the distillation of sulphur in the process of refining it, for which purpose much external heat is required. But if the fumes of sulphur or the coals be, after accession, intermingled with the due quantity of atmospheric oxygen they will, on the contrary, generate internally from the beginning their respective calorific effects."

Dr. Brett observes, in speaking of the supply of air required in

close furnaces, "every one who observes the volumes of black smoke escaping from the chimnies of manufactories must be struck with the positive loss of fuel thus sustained; yet not only is the black smoke lost for calorific effect, but a further loss may be traced to the passing off of what may be called a smoke, though not visible—I mean unburnt carburetted hydrogen and carbonic oxide. By mingling atmospheric air with the inflammable gases before they can escape unburnt, black smoke may be got rid of, or, in other words, that loss of fuel, and consequent loss of heat may be avoided. The importance of this supply of good instead of vitiated air, at the proper time and place; the no less important influence which a thorough commingling of the substances to be burnt, and the substance burning exerts in facilitating full and complete chemical union, and the injurious effects from a neglect of these precautions appears to be quite manifest, if we look to the nature of the elementary substances which enter into the composition of all ordinary pit coal."

It is constantly urged by those who are owners of smoking furnaces, that it is not worth the trouble and cost of preventing smoke, the fuel they use being so cheap; but they must admit that however "cheap" it may be, it still costs something; and it must thence be evident, that a "penny saved is a penny got," and that as we are all trying both to "save" and "get" pennies; which, by the way, soon make pounds; every penny saved from going up the chimney is a penny put in their pockets. If these persons, however, are so rich that they do not require to save "pennies" for their own advantage, let them, at least, learn to leave the atmosphere as clear and as pure as it is given us, and not make their furnaces nuisances to a whole neighbourhood, annoying alike to both rich and poor, without at the same time affording a single benefit.

Another great assistant to smoke-making in the ordinary furnace, is the thick heavy fire-bar with the very limited air-way, which its very thickness causes. Air being needed for combustion, it seems difficult to account for the use of these bars, when a moment's reflection must shew that the thicker the bar the more limited becomes the area or opening, whereby air can be admitted to support combustion. A great reform has, however, taken place of late years in this direction by the

employment of slotted-bars, argand-bars, and other contrivances, whereby a strong bar is obtained, and yet a great amount of air-way secured. Of these varieties the open-bar, known as Stratford's, seems to be the best, and one most caculated to obtain the end in view.

One of the members of our Society, Mr. Louch, specified, a short time since, a bar to be made of thin deep plates of wrought iron rivetted together, with pieces between, to give the necessary air-way. This bar has been found to give excellent results in practice, and has been used for a considerable period in the coal-burning locomotives of the Societé Couillet, and may be seen in the fire-box of a locomotive now in the Exhibition. These engines are stated to use the dirtiest description of small coal; so dirty, that it frequently has to be washed before it can be used, and it is said that without this plan of bar they could not use it. From the description of it, the fuel is not better than "breeze."

Now let us consider a moment what we are "practically" doing, when we are letting huge volumes of black smoke curl out of our chimnies, and from what we must find as the result of that consideration, the first step will have been arrived at towards alleviating the evil.

First, we build round our boilers and furnaces in brickwork, because it is nearly a non-conductor of heat, and that thereby the heat evolved from the coal burnt in the furnace, may be prevented from passing away and be lost. Next, we so arrange the flues or heat passages around and under the boiler, or through it, and amongst the water, as the case may be, that the heat may have every opportunity of passing into the water and forming itself into steam.

Then we *sometimes*, but not always, carefully cover up with non-conductors of heat our steam pipes and cylinders, which latter we also occasionally envelop in steam-jackets (through which as a variation the exhaust steam is taken), in order to prevent the loss of heat by radiation, all of which proceedings are highly commendable, and shew that up to a certain point we are disposed to be careful of our heat after we have extracted it from the coal.

Now, having done all this, taken this trouble, and gone to this expense, the question arises of "*what* has all this been done for?"

The answer is, to save money, or rather steam, for steam is money, and get as much work out of a given quantity as possible. All this is *only a partial* saving; it is saving at one end and losing at the other, for so long as by improper construction of furnaces, or by want of proper arrangements, we allow a portion of the fuel put into that furnace to pass unconsumed out of the top of the chimney, and without converting a portion of the water into steam, we are not working with the full amount of saving to which we are fully entitled, and might easily obtain, were proper attention given to the subject; and then we should find, from being thoroughly awake to its importance, that we had taken the next step towards preventing smoke, as we should quickly adopt those means which would secure this desirable result.

It would seem to be anything but an evidence of the wisdom of "practical" men, when we see them first fill a boiler with any amount of small tubes, through which they cause the heat to pass, with the avowed intention of getting out of the fuel all the heat it contains, and then employ that fuel in such a manner that it deposits in all the internal surfaces of these tubes a large amount of non-conducting matter, by means of which a great amount of their "practical" effect is diminished; and yet this is the daily practice with tubular boilers, where coal is burned without any means being taken to prevent the formation of smoke. It would seem here that a *little* theory engrafted in this large amount of "practical" knowledge would not be out of place.

In marine boilers little attention has been paid to what is taking place during combustion, and the necessity of making them occupy as *little* room as possible, has led to deficient boiler power, requiring hard firing, which is not by any means conducive to smoke prevention, nor even to obtaining the full practicable duty of the coal burnt, and the proportions between engine and boiler are so restricted, that perfect or even decent combustion is not easily obtained.

Smoke may, however, be greatly diminished in them, if judgment be used in applying the means, and care be taken to see that they are used, and not neglected and suffered to get out of order. Whilst on the subject of economy in the use of fuel, it will be well to make a few remarks in regard to feed-water heating, its desirability and advantages, especially in the case of high-pressure non-condensing engines, where the

steam which has done its work in the cylinder is blown into the atmosphere, and not used for creating a draft in the furnace.

As it would take too long to go into the history, merits, demerits, and description of the various plans which have been patented or used from time to time, and which are of all possible and impossible descriptions, it will be enough to enumerate what a good feed-water heater should be, what it should do, and why it should be employed.

The first grand requirement in anything, especially from a popular point of view, is *cheapness*, and this is particularly the case in anything relating to steam engine improvements, where it is generally found that if an engine works at a certain cost there is not much inclination evinced to adopt even a cheaper improvement, by means of which a further economy might be obtained in its working, unless such an improvement be very cheap indeed. From this it will be evident that one great requirement in a feed-water heater is cheapness, and it may be said that after that come efficiency, simplicity, freedom from liability to derangement, ease of management, and the capability of being cheaply and easily applied in those situations where its services may be required.

A good feed-water heater should, in the smallest possible space, with the smallest amount of superintendence, do the greatest amount of work, run for the greatest length of time without repair or diminished efficiency, and with as little wear and tear as possible, and heat the cooler feed passing into the boiler to as near the boiling point as possible.

The reasons why a good and simple feed-water heater should be applied to all steam engines are numerous, but the chief and most important is on the score of economy or saving, as it is rightly termed; and if we remember that it is said that the very best engines yet made only give from one-twelfth to one-ninth of the theoretic duty contained in the fuel burnt, it must be admitted that there is room for a greater economy than we have in practice. Let us take for example an engine burning 20 cwts. or 1 ton of coal per day, doing a certain amount of work, and let this engine, when the steam has done its work in the cylinder, exhaust it into the atmosphere, and thus suffer it to go to waste with a considerable amount of heat in it, which heat is thus dissipated in the atmosphere and lost. Now it is evident that any

portion of this heat saved is a clear gain, and if it be returned to the boiler in the shape of hot feed-water it will be evident that a greater amount of duty will be obtained from that boiler with a given weight of coal than when cold feed is pumped in, and a corresponding saving of coals result. We will assume, for the sake of argument, that the coals cost £1 per ton, or 1s. per cwt., or £1 per day: now if we can save, say two cwts.—2s. per day, from the waste heat passing off in the exhaust steam, by the use of a cheap and effective arrangement for this purpose, few will say that this is not worth doing, and more will be found to try it.

Fig. 5. shews in section and elevation one variety of just such a simple and compact apparatus, in which the steam, taken by a short pipe from the exhaust or blast pipe after it has been used in the cylinders, is projected into a short tube leading into the heater, and is delivered amongst the feed-water, which enters the heater in a thin annular sheet around the steam nozzle. In this short tube, or chamber, the water is broken into spray by the steam which is instantly condensed, and the water is raised to a high temperature, at or near to the boiling point, and runs into the pump or small cistern by it, and is than pumped into the boiler. In trying the working of this arrangement on a bitter cold day in the month of February, the feed-water entering the heater was at a temperature of 39°, and after it had gone through the heater, passed out at a temperature of 191°, at which it was pumped into the boiler. The engine used 20 cwts. of coal per day without the heater, and when it was put in operation the consumption fell to 18 cwts. It will be seen that this arrangement can be easily applied to locomotive and agricultural engines on wheels, where simplicity, lightness, compactness, and ease of application are of importance, and it is also of easy application to engines of all descriptions, and from its being free from any liability to get out of order, easily get-at-able for cleaning, and possessing no complication of parts, it will, no doubt, be of very extended application. This arrangement has been patented by Mr. D. K. Clark, and is the simplest plan of all others for accomplishing this desirable purpose.

It was once proposed that an association or society should be formed to receive and consider propositions for abating the nuisance of smoke, with funds, obtained by subscription or otherwise, sufficient to buy

up any patent that might be deemed adequate to the purpose, and then by enforcing the acts of the legislature to see it carried into effect; but it is not found that any steps were taken to carry out this very desirable undertaking.

Now that it seems to be the intention of Government, by its Metropolitan Smoke Bill, to enforce more rigidly on owners of engines and other furnaces the consumption of the smoke arising from them; it will be necessary to see that the circumstance of having put up the proper apparatus for effecting that object, shall not be admitted as a sufficient defence, in case of an action or indictment, where continuance of the nuisance proves that the means, though thus admitted to be at hand, are not sufficient, otherwise any law will produce little effect.

One thing is very evident, that so far as London is concerned, considerable improvement has taken place in its usually smoky atmosphere, but a great deal still remains to be done towards further diminishing, if not altogether preventing, the clouds of smoke which still appear around us. It is practicable to divest our manufacturing operations of a great portion of the evil at present attached to them, namely their smokiness, by obtaining a more perfect combustion of the coal used, and at the same time a considerable economy, by that operation.

In diminishing smoke much no doubt depends upon the determination of the owners to set about it and have it done, and having had the means applied, resolutely to enforce its employment by the firemen or others into whose hands its working may fall. In the majority of cases, when the management of an arrangement for this purpose is left entirely to the superintendence of the stoker; it either only partially fulfils its purpose or is found to be entirely useless, from the neglect and indifference of this individual, who well knows that any fine or action for non-prevention of smoke will fall on the master, not on himself. It would be a very desirable thing if all those who apply a plan for the prevention of smoke in their furnaces, would make themselves acquainted with its operation, see that it acts well, and having done so, take such precautions or make such arrangements that in case of any smoke appearing, the party in charge of the furnace shall suffer by a fine, this would strike at the root of the evil and make

the men take an interest in their work, which at present does not seem to be generally the case.

There can be little reason to doubt, that if the public were once satisfied that smoke might be prevented by cheap and simple means, that its prevention would be at once carried out. Nothing can be more detrimental to the carrying out of any desirable work, than the idea that "it can't be done," an idea, that once fostered, is almost ineradicable. There seems to be a good opening for an "association to prevent smoke and promote economy in the use of steam," which, if properly and judiciously worked, and resolutely carried out, would be the means of conferring a great benefit on the dwellers in neighbourhoods where steam is employed, and at the same time beneficial to the users of steam power. We have seen the success attending the Manchester Steam Boiler Assurance Company, which supplies a want long felt, whose operations are extended over nearly the whole kingdom, and with such success, that it has completely extinguished an undertaking which had no such advantages to offer, although backed by a strong array of science, and is shaking to its very foundations another affair similar to the one it has already extinguished.

On railways the use of coal is rapidly extending, and, in fact, may almost be said to have superseded the use of coke, but its employment is unfortunately not free from the great drawback and nuisance of smoke. Numerous attempts have been made to prevent or burn the smoke evolved from coal during its combustion in the fire-boxes of locomotives, and with what amount of success, we have only to watch any of the engines on the lines leading out of the metropolis to see; and that there is great room for improvement no one can doubt. When the Railway Act empowering railways to use steam-engines was passed, it was rendered compulsory on all railway companies, by that Act, not to produce any smoke. The Railway Act of the 7th Geo. 4th, especially provides that each engine shall "effectually consume its own smoke." How well the Act works, a journey on any coal-burning line will afford ample and unanswerable proof.

Some of the systems of smokeless coal-burning require nearly an entire reconstruction of the fire-box, others require engines to be specially constructed for them, and the remaining portion are easily

applied to the coke-burning engines at present in use. They may be classed as follows:—Those with large spacious fire-boxes containing one large grate, or else divided by a feather into two, with a fire-door for each with long runs, such as those of M'Connell, Beattie, and Cudworth; these are further divided into long tube, short tube, combustion chamber projecting into the barrel of the boiler, and other varieties, in which the use of firebrick and other materials for keeping up a high degrees of heat, and splitting the hot products of the fire-box into as divided a state as possible, are employed. Then those with deflectors or baffle-plates to deflect the air down upon the fire admitted, either from the fire-door or elsewhere,—these are generally applicable to existing locomotives; and, lastly, the plan of introducing, currents of air uniformly distributed over the surface of the fuel through tubular or other openings in the side of the fire-box. This last plan is easily and cheaply applied to any existing engine as constructed with the ordinary square fire-box.

The same remarks that apply to the thorough mixture of a proper quantity of air with the products of combustion in ordinary furnaces are equally applicable here; and it is found in all those plans in which the air is admitted in bulk, that a large quantity of that air escapes unconsumed through the tubes, and at high speeds tends to diminish the production or keeping up of steam. Another objection to the use of the "baffle" "deflector" or "shovel," to say nothing of their requiring rapid renewal, is their causing the suction, as it were, of particles of coal through the tubes, and the burning of the smoke-box in consequence, unless this were counteracted by the use of the brick arch in the fire-box. If any one examine the smoke-box of an engine fitted on this plan, just as she comes off her journey, they will find this to be the case, and also that there will be a large deposit of ashes therein.

Theory shews us, and experience has proved, that the thorough intermixture of the air with the combustible gases at or near the surface of the fuel is best attained when the air is distributed amongst them through numerous small openings, rather than through one or two large ones; and this can be perfectly done without baffles, shovels, deflectors, brick arches long fire-boxes, or combustion chambers, by

the simple employment of air tubes of small diameter passing through the water space either in the front and back, or at the sides of the fire-box, open externally to the atmosphere, and internally to the gases and heated matter, just above the surface of the fuel. Now this arrangement, originally patented by S. Hall, in 1841, which, where properly applied, is most efficient in destroying smoke when the engine is running, is not capable of doing it when the steam is shut off, and the powerful suction and mixing action of the blast is lost; and this is the same with all plans acting by the force of the blast. To overcome this difficulty, the steam-jet in the funnel has been added to all of the ordinary plans in use, but with a very small amount of success. The use of this jet or blower is objectionable; first, because so long as it is in use the steam is continually rising, the fire kept bright, and fuel and steam wasted; and, next, because it does not fulfil the end to which it is applied, from its strongest action being in no way equal to the blast of the engine when running, and thus not capable of maintaining that rapid and thorough mixture of air required for prevention of smoke; nor is it capable of suiting itself to the quiet state of the fire when the engine is standing, or the ever varying conditions of a locomotive furnace.

The means of overcoming these difficulties and extending the range, volume, and power of the air currents, and of adjusting them to the wants of the furnaces, has been admirably obtained by Mr. D. K. Clark, C.E. (who has patented it a few years since), and consists in inducting, accelerating, and thoroughly intermixing the currents of air within the box, by the instrumentality of minute jets of steam. By this arrangement (as shewn in Fig. 13), the steam nozzles with the air-tubes to which they are pointed, are like so many miniature blast pipes and chimnies turned into the fire-box, possessing relatively the same power of urging and creating the draft; and the air-currents are by this means delivered with such precision and velocity, as to sweep over the whole surface of the fuel, and forcibly distribute and mix the air amongst the gases, whereby a complete and entire prevention of smoke is attained.

In practice it is found only necessary to use the jets occasionally when the engine is at work, say just as a charge of coal is being

thrown on, so as to make the fire rather green, the blast as before shewn introducing nearly air enough, but the time when their use is in demand, and by which smoke is entirely prevented is immediately on shutting off the steam, when coming into a station or otherwise. Then the heat in the fire-box is fierce, and a great distillation of combustible gases will be taking place, all of which, if not met and consumed by the steam inducted air currents above the fuel, must escape at the chimney in the shape of clouds of smoke. The intensity of the heat will now rapidly subside, and the jets may be moderated as desired, and continued in action until the engine again starts off. The indraught of air into the fire-box can be easily regulated by the use of slides or dampers over the air openings, but by so proportioning the area of hole as to prevent any great excess of air supply, the dampers may be dispensed with altogether.

The following statements of the working of this plan in comparison with others will be a satisfactory proof of the economy and efficiency of it. The gross weight of engines and tenders were nearly equal, and trains of 100 to 116 tons, speed nearly the same, and the coal consumption as follows :—

		Per Ton gross.
Mr. McConnell's plan	... 36½ lbs. Hawksbury coal, per mile	·31 lbs.
„ Beattie's (with cold water)	24 lbs. Griff and Stavely, „	·235 „
„ Cudworth's	26 lbs. coking coal, „	·225 „

When tried (as used by Mr. Cowan on the G. N. of S. R.) in competition with those plans adapted to the ordinary fire-box (with passenger trains) such as Mr. Douglas of the Birkenhead Line, with a close deflector, Mr. Yarrow's of the Scottish North Eastern Railway with a brick arch and air bars; Mr. Connor's of the Caledonian Railway, with a brick arch and door deflector; Mr. Frodsham's of the Eastern Counties Railway, with a door deflector and steam roses in the fire-box, as used by Mr. Sinclair; the following results were obtained :—

	Gross weight.	Gross coal. per mile.		Per ton gross. lbs.
Mr. Douglas	90 Tons	28·4	or	·32 (Welsh.)
„ Yarrow	86 „	25·7	„	·32 (Fifeshire.)
„ Connor	88 „	22·2	„	·26 (Lanarkshire.)
„ Frodsham	93 „	23·3	„	·25 (Staveley.)
„ Clark	110 „	21·0	„	·19 (Fifeshire.)

Shewing that with the system of steam inducted air currents forcibly mixed with the gases better combustion was obtained and less coal used with a heavier train than by any of the others.

In the working of goods trains similar results followed, as will be seen by the following table:—

	Gross weight.	per mile.	lbs.
Mr. Douglas	...... 445 Tons.	..... 60·3 lbs. or	·135 per ton gross.
„ Connor	...... 255 „	...... 37·3 „ „	·147 „ „ „
„ Frodsham	...... 228 „	...... 41·5 „ „	·182 „ „ „
„ Clark	...... 305 „	...... 39·6 „ „	·130 „ „ „

The Great North of Scotland Line, on which Clark's system of smokeless coal burning is in full operation, all the engines being fitted with it, has long gradients, several varying from 1 in 100 to 1 in 150 with frequent curves; and the goods engines could take up these inclines 35 fully loaded waggons, = 460 tons gross weight, at 10 miles per hour. Mr. Cowan, the Locomotive Superintendent, in speaking of the plan, says, "should any person wish to see it working, they may travel on the engine for a week, and satisfy themselves that smoke consumption is a fact accomplished really and truly, and by simple means. Its application as a damper whilst standing is a feature peculiar to this system alone, and of the utmost importance in practice. It is used here daily for that purpose. By the use of it properly, an engine could be kept standing twelve or more hours, and the steam not vary a pound up or down, and yet in three minutes the engine would be in readiness for any train. By its use an engine with a full fire unexpectedly stopped in the road can be easily managed."

It may be remarked that Mr. Cowan had personally examined and tried all the systems of locomotive smoke prevention in use, and unhesitatingly adopted this in preference to all the others, it being so simple and efficient. Numerous opportunities have been afforded to the author of examining and travelling with engines fitted with most of the plans of smokeless coal burning, but none of them came up to that of D. K. Clark, which system is distinguished above all others by its simplicity, durability, efficiency, and simple management. It has no construction of any description within the fire-box, and

is not therefore subject to wear and tear from exposure to intense heat, and although it commands the entire range of the fire-box, it does not in any way interfere with, or cause extra labour in the management of the fire. The whole business of smoke prevention by its use, consists in occasionally causing the inducting jets, which are placed sufficiently above the fire to command it at all times to operate, by means of a tap or cock near the hand of the engine driver, and an occasional help from the ring jet in the chimney to carry off the products of combustion. By the proper use of this system the fire may be "damped" or kept dull when desired, when for example an engine has to wait at a station, without raising the pressure of the steam, as the forcible indraught *above* the fire, is made to prevent a draught *through* the fire, and thus check or suspend the combustion of the fuel, conducing both to safety and economy, and contrasting favourably with the other systems, in all of which, as before remarked, a powerful blower is needed when standing, incurring thereby dangerous pressure and a waste of steam. It only needs trying or to be seen in operation by unprejudiced persons, to secure its use wherever it is really desired to burn coal without smoke.

It should be strongly recommended, that whatever plan the owner of a furnace may choose to adopt, he should feel it incumbent on him especially for his own pocket's sake, to apply either to the patentee or owner of such plan, or else to the agent, in order that the proper carrying out of the erection or alteration may be secured, and that the necessary instructions given may be precisely followed. This is due in common fairness to the party whose plan may be followed, because it is found that either from want of thoroughly understanding the principle, or else from the idea that an improvement may be introduced, many good and simple arrangements have utterly failed, and the interests of the inventor or proprietor have been thereby seriously damaged.

It has been usual to consider Watt as the first or earliest inventor of a furnace to consume its own smoke, and possibly this may be correct in so far as it relates to steam engine furnaces. In the seventeenth century, however, it appears that apparatus for this purpose was

employed in many manufactories in France. In the volume of the Academy of Sciences for 1699 some experiments are given of a M. de la Hire, which have reference to an invention made many years previous by M. Delasme, a French engineer. This latter gentleman, we are told, exhibited his furnace for consuming its own smoke at the fair of St. Germain, in the year 1685.

1772, John Aysel, London, "Improved Furnace."

1785, R. Cameron, "Furnace for consuming Smoke."

In June, 1785, Watt patented several modes of consuming smoke in furnaces, many of which have been re-patented of late years, such, for example, as passing the smoke and gases from one fire over the bright coals in another; causing the gases and smoke from the fresh fuel to pass through very hot tunnels or pipes, or among, through, or near fuel which is intensely hot, and has ceased to smoke, and by mixing it with fresh air under these circumstances.

In 1796, a Mr. Thomson, of London, patented the hanging bridge or brick arch, and the admission of air through a slit or opening behind the bars, regulated by dampers, nearly similar to Park's split bridge.

1796, J. Pepper, Newcastle, "Saving Fuel."

1796, F. Lloyd, Woolstanton, "Furnace.'

1797, J. Grover, Chesham, and T. Rountree, London, "Furnaces."

1798, W. Bayley, York, "Furnace."

In 1813, Benjamin F. Coombs, of London, patented, and in 1819 described "Plans for saving fuel and suppressing smoke," in which a feed hopper and crushing rollers were used; the grate raised or lowered by means of rackwork, and air admitted to the fire by flues at the front and sides.

In July, 1815, William Losh, of Newcastle-on-Tyne, obtained a patent in which he proposed dividing the furnaces into two; in one case they are placed side by side, and the smoke from the fresh fire in one, turned by means of dampers over the other bright one; and in the second they were placed end to end, and by means of doors fitted to the ash-pits, and dampers, the smoke is driven into the ash-pit and out through the coals in the clear fire.

In 1816, Joseph Gregson obtained a patent for improvements in

furnaces and preventing smoke, which consisted of an opening in the fire-bridge, through which the current of air was admitted.

In 1816, W. Brunton, of Birmingham, patented his well-known circular revolving grate, with feed rollers for crushing the coal on its way to the fire. This plan was brought up again in 1819, by John Steel, of Dartford.

In 1812, John Walker, of Kennington, described to a committee of the House of Commons his plan of burning coke alone in fires with additional flues.

In May, 1820, Josiah Parkes, of Warwick, patented his plan of admitting air from the ash-pit into a hollow bridge, thereby projecting it in a sheet upon the gases and smoke at the back of the fire.

In December, 1820, John Wakefield, of Manchester, patented his particular mode of placing checks or stops in the flues of the furnaces, and also placing the bars "radiantly" or closer together in the front than the hinder part.

In February, 1821, William Prichard, of Leeds, patented the use of a cylinder and piston, with a branch pipe between the two ends of the cylinder, allowing a quick or slow passage of the air according to the adjustment of a stop-cock. A chain from the piston rod passed over a pulley and was connected with the fire-door, which, by the sinking of the piston as the air escaped, shut the door gradually without the aid of the fireman. Here we have a self-regulating door as nearly as possible that of T. S. Prideaux patented many years after.

In March, 1822, George Stratton, of London, patented a plan for heating a boiler by means of two fires—one in front and the other under the middle of the long boiler, both being fed with coal by feeding pipes passing downwards through the boiler.

In July, 1822, John Stanley, of Manchester, patented his self-feeding apparatus, consisting of a copper containing the coals, at the bottom of which were placed two grooved rollers to crush them, on a plate on which they fell, and revolving fans to scatter them over the fire, the whole being moved by the engine or other power. This plan, it will be seen is very similar to Steel's, Brunton's and others.

In September, 1823, James Neville, of London, patented the use of a fan placed in a recess in the furnace flue, to be turned at a rapid rate

by the engine or other power, and force the smoke and hot air up the chimney, fresh air being drawn in through perforated plates in the cross flues, and thus consume the smoke.

In 1824, Mr. Jeffrey, of Bristol, patented a plan for preventing smoke, by causing a down draught through a shaft in which a constant shower of water was falling, so that he condensed it.

In the same year, George Chapman, of Whitby, introduced hollow fire-bars open at the front ends to the atmosphere, and opening at the back end into a slit about an inch wide in the fire-bridge, which opening inclined slightly forward so as to reverberate the air back in the fire. (This plan of bridge is similar to Park's split bridge.) In the same year, R. Evans, of London, used a tube perforated at one end with small holes, and at the other connected with the waste steam-pipe of the engine. He placed the end with the small holes under the fire-bars in the furnace, and by means of jets of steam endeavoured to kill the smoke. He eventually found, however, that with the use of coke and strong steam he succeeded better, as he maintained an active combustion. It may here be remarked, that blowing a jet of steam under the fire is now used in several gas-works.

In 1826, James Barron, of Birmingham, patented a plan for feeding furnaces without opening the fire-door, and causing all the air required for combustion to pass through the bars. This was done by means of a large vertical tube nearly over the furnace, through which, by a self-acting arrangement, the fuel dropped on the fire at stated intervals.

In the same year, a Mr. Jacomb, of London, patented a revolving grate or cage in which coal was burnt, and this was applicable for domestic purposes also.

In 1828, James Gilbertson, of Hertford, patented a furnace to consume its smoke, in which the air was heated by passing between hollow plates fixed at the side of the fire, and thence into a cavity at the back of the fire, where it ascended through a grating above, and came in contact with the smoke, thus causing it to ignite.

In June, 1831, Samuel Hall, of Moorgate-street, obtained a patent for the use of heated air supplied to furnaces for the purpose of consuming the smoke, which air he heated by causing it to pass through a number of cast iron pipes placed in the flue leading to the chimney, so

that it might employ that portion of the heat which had not been used in raising steam.

In September, 1834, John Chanter, of Blackfriars, London, obtained a patent for various improvements in boilers and furnaces, which consisted in gradually drying and preparing the coal in the furnace, so that the liberated gases were burnt in the hottest part, the air being supplied by means of a tube under the first fire-grate in the centre of the furnace, two grates being used in this plan. This has lately been re-patented.

In June, 1836, John Hopkins, of Clerkenwell, obtained a patent, in which he set forth the use of a fire-bridge of a curved form intended to arrest the heat and flame together with the smoke, and throw them back from the end of the furnace, and cause them to pass again over the surface of the burning fuel. On marine boilers and others where desirable it was proposed to construct the bridge of metal and hollow, and also connected with the main boiler.

In February, 1838, a patent was granted to Michael Wheelwright Ivison, the principle of which consisted in the discharge of a very small quantity of steam, not through the fuel or down upon it, but above the fuel and through the products of the fire.

In August, 1838, Richard Rodda, of St. Austell, Cornwall, patented the employment of fire-brick passages strongly heated, through which the smoke, having passed through the fire, was made to pass. The smoke was previously mixed with a due proportion of atmospheric air, admitted through a valve or box over or near the fire-door, which valve was opened or shut as the gases required.

In the same month of the same year, David Cheetham, junr., of Staleybridge, patented the use of a fan placed in such a position as to catch the most inflammable portion of the gases, and propel them with a certain proportion of atmospheric air into a close ash-pit, so as to cause it to pass through the fire.

In October, 1838, Paul Chappé, of Manchester, patented the injecting of a sheet or numerous small jets of boiling water over the fire in front of the bridge, by which he intended to effect the combustion of the smoke (or, more probably, the extinction of the fire.) He also proposed a similar jet to be projected at either end of the flues, or in

the chimney, the water to be supplied by means of pipes from the boiler.

In November, 1838, James Drew, of Manchester, patented the use of fire-bars in two sets, the front half being laid on fixed bearers in the usual manner, and those at the back on a frame capable of being raised or lowered by means of rackwork or otherwise. The front bars received the fresh fuel, which, as soon as red hot and charred, was to be pushed into the second or movable set of fire-bars, and raised as near as might be desired to the bottom, the smoke from the fresh fuel being burnt in passing over the fire in the back grate.

In February, 1839, Thomas Hall, of Leeds, patented the division of furnaces and alternate firing, precisely as Losh had done in 1835, and others since.

In June, 1839, Charles Wye Williams, of Liverpool, patented his argand furnace, which consisted in the use of pipes or plates perforated with numerous small holes, and placed either in the furnace or so near it, that the air entering in a finely divided state amongst the gaseous products of the furnace would, by commingling with them, produce more complete combustion and thus prevent smoke. This plan was originally introduced by a Mr. Stoddart, of Glasgow, in the year 1827, but abandoned in consequence of its having been found to damage the boiler.

In August, 1839, Richard Prosser, of Birmingham, patented a plan in which he used a hanging bridge (similar to those of Chanter and Rodda, several years before), placed some distance from the ends of the fire-bars; the gases were thus obliged to pass through flues or openings in the bridge into a chamber beyond, and thence to the chimney, the space between the end of the bars and the bridge was fire-brick, forming an inclined plane on which the hot fuel was to be pushed, keeping them hot, and burning the smoke.

In November, 1840, André Kurtz patented a plan for consuming smoke by placing the bars in a peculiar position in the furnace, using three sets, and inclining those at each end towards the middle set, which were horizontal and lower than the two ends of the furnace. He placed these bars in hollow bearers open to the ash-pit, and connected with apertures in the furnace. There were air passages closed by doors, and only opened occasionally to clean the flues, the

fire-door being shut and the ash-pit also closed, except a slight opening for air, which, rushing through the hollow bearers and becoming heated, was expected on entering the furnace to prevent the formation of smoke.

In January, 1841, Edward Foard, of Islington, patented a plan in which the furnace was supplied from below, the bed or frame carrying the bars being lowered while the red hot fuel in the furnace was supported by a sliding plate or false bottom; the plate was then withdrawn, and the smoke mixed with air rising through the bright fuel was, it was thought, consumed.

In February, 1841, the Baron von Rathen, of Hull, patented his undulating fire-grate, in which the bars were double or hollow, resting on bearers with steps, thus ascending or descending, forming two sides of a triangle, including spaces or hollows in which the fuel was placed. He thus enlarged the area of the contact of the air with the coals. He also proposed to use a coal-feeder placed over the dead plate having a movable door, with a lever projecting outside, by which the fireman could shake the coals forward so as not to open the fire-doors; air bars on the side of the fire-grate so as to let a small portion of the air outside enter the close fire-box; and two ash-grates with small round bars one over the other, on which the ashes and hot cinders from the upper grate were to fall, so as to prevent the cold air rushing up in a mass to the large fire, and thus warm it on its passage.

In November, 1842, John Cooper Douglas, of London, patented a plan by which the gases were to pass over a bridge under another bridge into the space beneath another set of fire-bars, whence they were to pass off, burning the smoke by passing through the second fire. This was before done by Losh in 1815, and others since.

The author would remark in concluding this paper, that great merit is due to Mr. Charles Wye Williams for his chemical investigations regarding smoke, and the great care and attention he has paid to this subject. A glance at the way in which it has been usual to try and "burn" the smoke will prove at once how little chemical knowledge has been displayed by numerous patentees for this purpose, and how little trouble they gave themselves to become acquainted with the nature of the substance they proposed to deal with.

DESCRIPTION OF DIAGRAMS.

Fig. 1 represents the usual amounts of smoke to be seen in the chimney-tops of ordinary factories where no apparatus is used.

Fig. 2 shews the appearance of the fire producing such smoke, and the imperfect combustion arising from want of air.

Fig. 3 shews the state of the fire in a well-proportioned furnace where the air is properly and sufficiently admitted, and combustion is nearly perfect. In this furnace no more smoke would ever be seen than is shewn in the least amount in Fig. 1.

Fig. 4 shews the appearance of such a fire as Fig. 2; when the steam-inducted air currents are applied, the smoke being at its worst reduced to No. 2, Fig. 1.

Fig. 5 represents the feed-water heater before described. The steam-pipe is shewn at the top, the feed entrance at the side, and the pipe to the pump may be at the bottom or on one side, as shewn.

Fig. 6 is a section and half plan of a coal-burning locomotive on Mr. M'Connell's patented principle for using coal without smoke. It may be here remarked that the best test of the efficiency of the plans named, is either a journey behind one of the engines or else a residence close by the line.

Fig. 7 is a longitudinal section and half plan of Mr. Beattie's patent, as used on the London and South-Western.

Fig. 8 is a half plan and longitudinal section of the long-inclined fire-grate of Mr. Cudworth, as used on the South-Eastern Line.

Fig. 9 shews the plan of Mr. Douglas, as used on the Birkenhead Line.

Fig. 10 is a longitudinal section and end view of the system of Mr. Yarrow, on the Scottish North-Eastern.

Fig. 11 shews the plan of Mr. Connor, as used on the Caledonian Line.

Fig. 12 is that of Mr. Frodsham, as used by Mr. Sinclair, on the Eastern Counties.

Figs. 13 and 14 are two variations in the application of the steam-inducted air-currents as patented by Mr. D. K. Clark, Fig. 13, resembling that on the Great North of Scotland Line, as used by Mr. Cowan.

Fig. 15 is a longitudinal section and end view of the plan used by Mr. Jenkins on the Lancashire and Yorkshire; the curved slab shewn inside the fire-box was originally made of cast iron, but from their rapid destruction they are now made of clay.

Fig. 16 is a longitudinal section and end view of the plan of Mr. Ramsbottom, of the London and North-Western Railway, in which the air enters over the fire through two large square apertures, in the front of the box, under a brick arch, fitted with dampers to regulate the quantity.

Fig. 1.

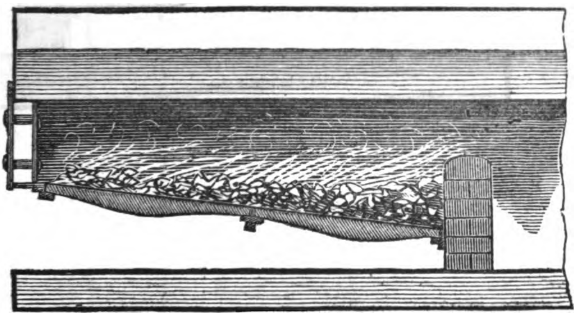


Fig. 2.

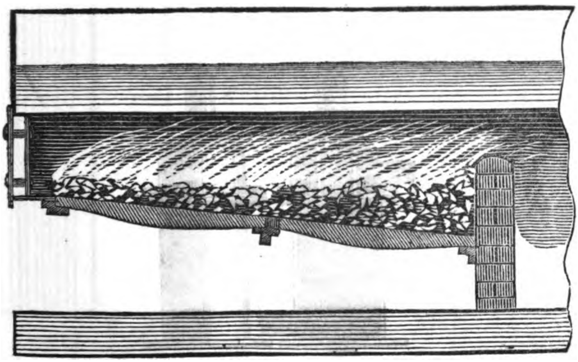


Fig. 3.

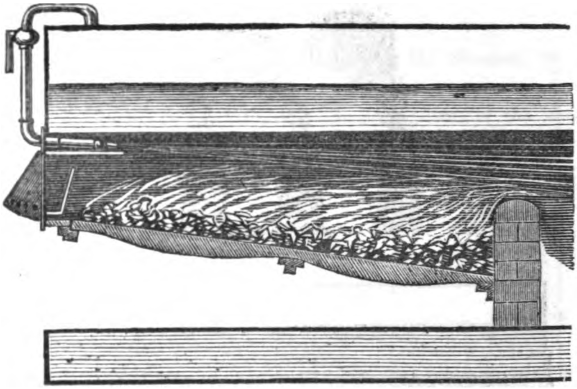


Fig. 4.

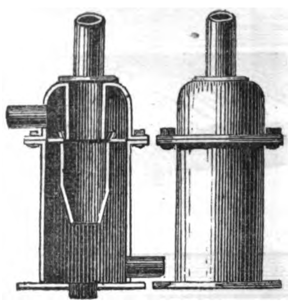


Fig. 5.

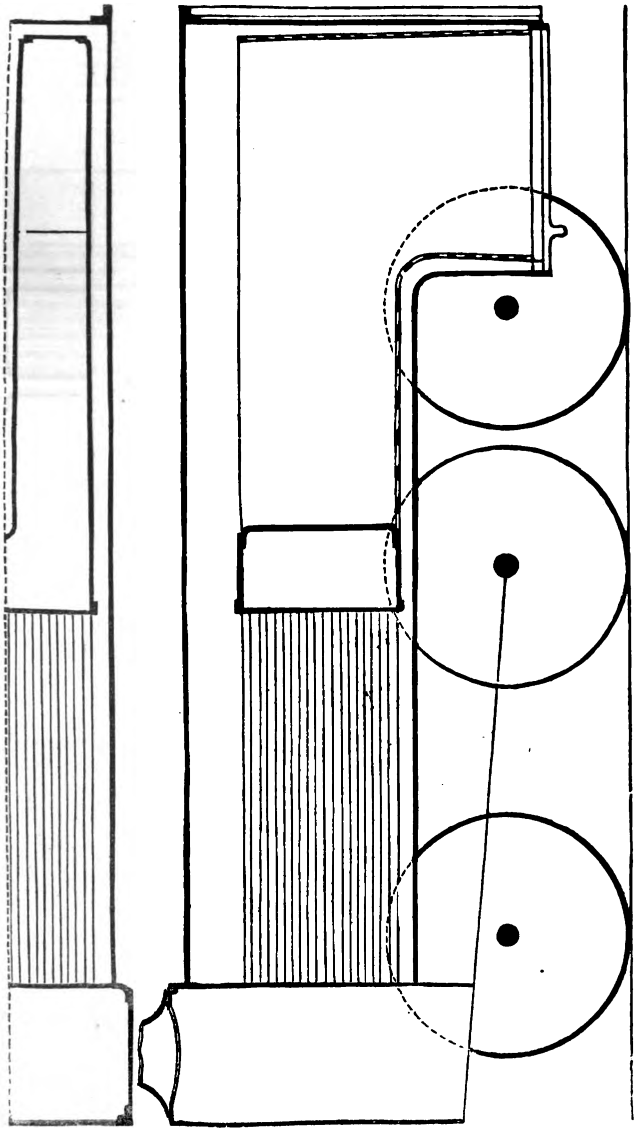


Fig. 6.

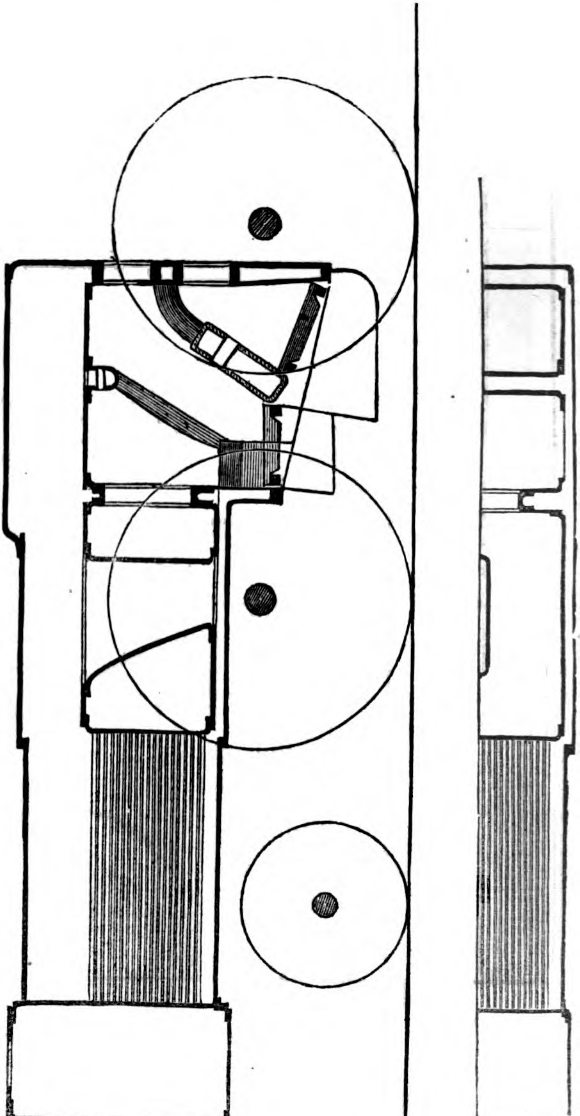


Fig. 7.

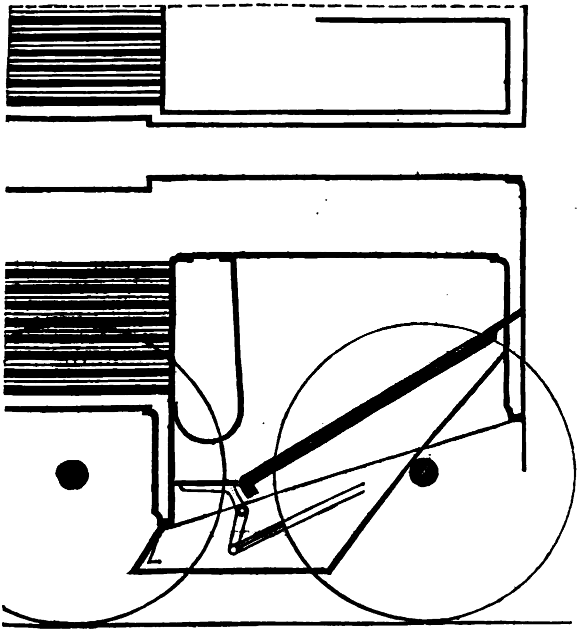


Fig. 8.

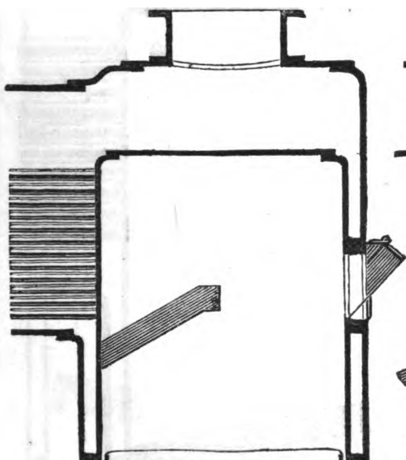


Fig. 11.

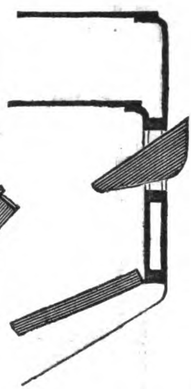


Fig. 9.

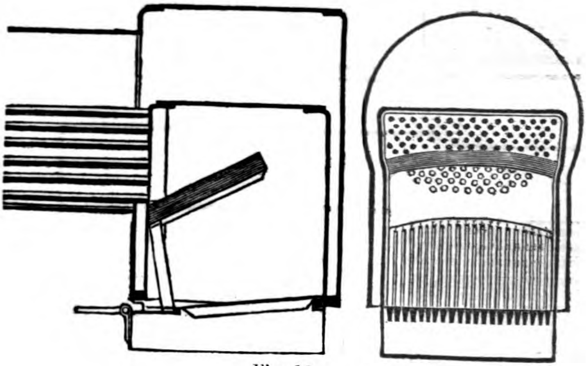


Fig. 10.

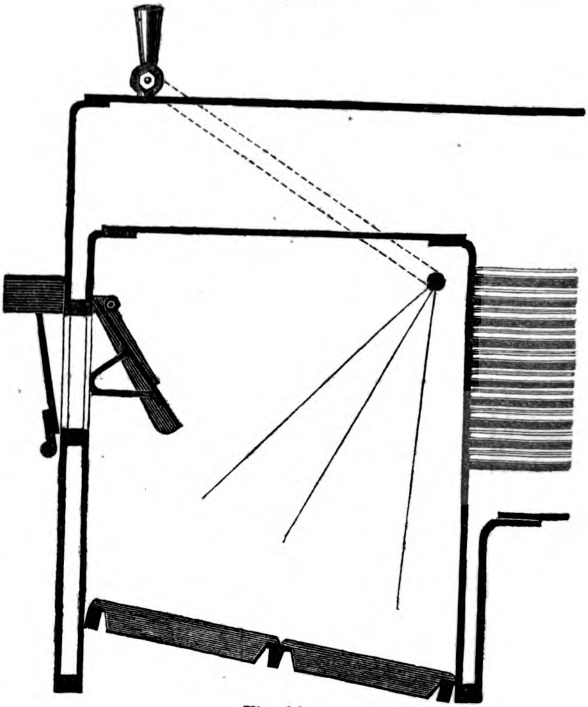


Fig. 12.

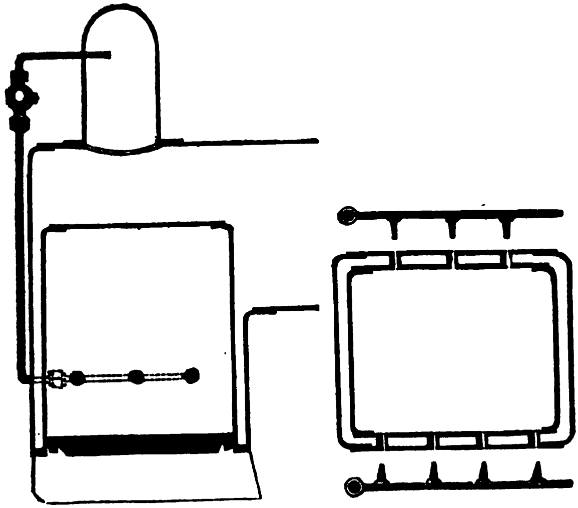


Fig. 13.

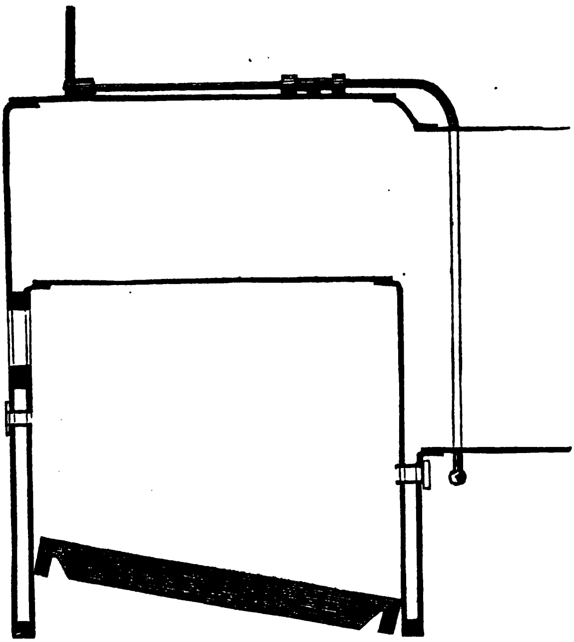


Fig. 14.

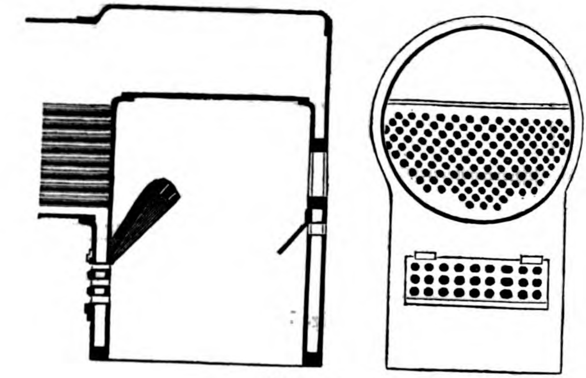


Fig. 15.

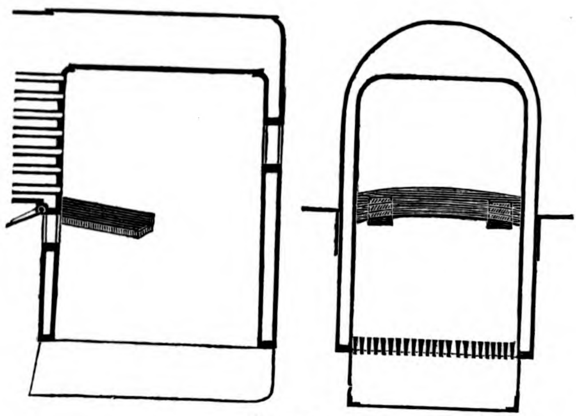


Fig. 16.

DISCUSSION.

Mr. Carrington described a furnace he had seen near Blackwall which Mr. Young had not mentioned. It consisted of two fire grates, one behind the other; the front grate was fed with slack, and the hot coke was pitched over on to the back grate each time the front grate was fed. The smoke was deflected by means of a brick arch, which threw the gas or smoke over the lower grate, the hot air that passed through the coke on to the back grate, mixed with the hot gas and made a whitish flame almost immediately. No perceptible smoke passed out of the chimney, and the stoker said there was not the least trouble in stoking, and that the steam could be got up in a much shorter time than with an ordinary furnace, and effecting a saving of 32 per cent.

Mr. Rumble explained by a diagram a smoke-consuming apparatus of which he is the patentee. It consists of a hopper and moveable front, to which is attached an inclined plane of peculiar construction on which the fuel falls, and is pushed forward slowly so that perfect combustion takes place; no smoke is to be seen, and clinkers to a great extent prevented. The admission of the requisite air is given by opening a flap; the supply of fuel is regulated by a slide and by a greater or lesser motion of the moveable front and inclined plane. Its great advantages are, that it costs less than any efficient plan at present in use, requires less labour, and has the great advantage of allowing the fire to be cleaned and urged, and enabling the stoker to get up the steam briskly when required. It was his opinion that if coals were put upon a fire very slowly indeed, smoke would scarcely ever be met with.

Mr. Louch having tried many experiments in connexion with this subject, had come to the conclusion that the necessary amount of oxygen should be as far as possible supplied to the fuel at the moment when ignition takes place and not after the smoke had been formed, and drew attention, as an example of a perfect smoke consumer, to the ordinary camphine lamp, which he explained by means of a diagram. This principle, he was of opinion, should be carried out as far as was

practicable in all furnaces where it was desirable to consume smoke. This should be effected by admitting as much air as possible through the bars, which should on that account be made much thinner than those now generally in use. If the grate surface were too small to admit of sufficient air being supplied by this means, it would be necessary then to perforate the door or otherwise admit a sufficient quantity of air above the fuel; which, however, should be avoided as much as possible, as in this case he had found that the smoke was only consumed at the cost of fuel, notwithstanding the statements to the contrary issued by the numerous inventors (?) of this plan of consuming smoke. It was necessary to keep the bars as clean and free from clinkers as possible. This could be effected by means of the several varieties of reciprocating bars now in use, originally the invention of the late Mr. Chanter. The nature of the coal should also be studied, and it was a mistake of many to insist on using large blocks of coal. The best size to effect combustion is about the size of a man's fist, so as thoroughly to disseminate the air through the fuel; if used much smaller the furnace becomes choked; if much larger the spaces between the lumps are fewer in number, therefore before firing the coal should be reduced as near as possible to this size. No means for the consumption of smoke however, would be successful without very careful stoking. Mr. Louch also described Juke's smoke consuming grate, in which the bars were caused by machinery in connexion with the engine to traverse the furnace longitudinally and carry with them the fuel, which being thus gradually supplied to the furnace, was consumed without emitting any dense smoke. This principle was also carried out in Brunton's revolving grate. Mr. Louch had seen one of those grates in good working-order which had been erected by James Watt, nearly fifty years since.

Mr. Olrick was fully satisfied that when smoke was once formed it was impossible to burn it. He considered the invention of Mr. C. Wye Williams for the prevention of smoke the best and the most simple, and quite correct in principle. It consisted in admitting a certain amount of air at the door or at the bridge, due care being taken to have a sufficient area at the bridge. Wherever this plan had been tried it had proved successful. He did not consider it correct to draw

conclusions from what could be done on the measured mile, but from the result of the working of the boiler after three or four weeks continued work. He knew of boilers that had been constructed for 20 lbs. of steam, but in consequence of being constructed too small 13 or 14 lbs. was the utmost that could be obtained. In constructing the boiler the first thing was to make the area of the grate the proper size, it being generally found much larger than it ought to be, thus causing the combustion to be very slow. If the area of the grate is the proper size, and the areas of the other passages correspond, there would be about 3200 degrees of heat in the furnace, which would enable the proper amount of cold air to be admitted. If the air is shut off there would be a dull brown flame, but when the air is admitted, the heat and light will be very intense. In a spiral boiler made by Mr. Elder, in Glasgow, the distance from the fire-grate to the chimney was 100 feet, or seven times larger than a common tubular boiler, consequently the former would be more usefully applied than the latter, no smoke escaped from a chimney in a trial of 8,000 miles without stopping, the coal consumed was as low as 2 lbs. per indicated horse power, whereas the usual amount in the British Navy at the present time is 5 to 6 lbs.

June 2nd, 1862.

E. RILEY IN THE CHAIR.

ON THE USE OF COAL IN FURNACES WITHOUT SMOKE.

ADJOURNED DISCUSSION.

Mr. F. Young said at the previous meeting Mr. Olrick referred to a Marine Boiler. This boiler consisted of an upright central boiler, around which another similar boiler was wound spirally, like a cork-screw, and all round these, other vertical boilers were placed, thus forming a compound or built boiler. When properly fired it produced no smoke whatever, as the gases and air became heated and mixed on their passage to the chimney, and when the air arrived at that point it left contact with any useful heating surface. The temperature of the waste heat was found not to exceed 500 degrees, while in other boilers it was 1,000 degrees, thus shewing a great saving of heat. This was

not the result of a trial trip, but of steaming 50,000 miles. The pressure varied from 40 to 50lbs. on the inch. This boiler was fitted with a man-hole, through which each part could be easily cleaned, and it seemed to fulfil all the requirements of an efficient marine boiler, by it, sea-water could be used, and it could be worked at high pressure, and at the same time effecting a great economy in fuel; the cost was very little above an ordinary marine boiler.

Any description of coal could be used, but during the voyage referred to, Glasgow coal was used.

Mr. Olrick considered that more attention should be paid to the chemistry of boilers, and likewise to their construction. A paper appeared in the *Artizan*, 1860, which fully explained this subject. The amount of gas and atmospheric air that must pass through the different passages in the boiler should be calculated, and also the temperature at which they pass. The rules for this were based upon the assumption that you were making 25 ft. per second, and admitting 18 lbs. of air per pound of fuel—the rate of combustion multiplied by the area of the grate in square feet, and that product by a co-efficient different for each passage. The space over the fire should be as roomy as possible. If there was not a sufficient combustion chamber, it would not allow the proper mixture of the air and the gasses at the time it was required. The tubes were generally made too small. They should never be less than three inches diameter, nor should they be placed too high to expose them to the steam instead of the water, in which case they would be likely soon to wear out.

The Chairman said an important point had been raised with regard to the difficulty of burning smoke. He did not know if Mr. Olrick was aware that a furnace had been constructed in which the whole of the fuel was converted into gas, and afterwards burned. This was effected in a peculiarly constructed furnace, supplied with a blast, and so arranged that the air, or rather the oxygen, converted the carbon into carbonic oxide; only, in this furnace, no draught was required; and he questioned whether it was not much cheaper to produce a draught mechanically than by means of a high stack, which must be made hot, and consume a large amount of fuel to keep up the draught. The application of gaseous fuel was extending every day. The waste gases

from the blast furnaces were being applied for heating all the boilers, hot blast, &c., and had also been successfully used for puddling. He considered that there was an immense waste of heat in puddling furnaces—first, from the high temperature of the slack, and the unused flame that came from it; and, secondly, from the large amount of ashes which were always raked out in clearing the fire bars. This would be entirely obviated by using a mechanical draught, and converting all the ashes into a fusible cinder, in a furnace of somewhat the same construction as a blast furnace, only on a small scale. The waste gases would require no slack, and might be consumed under the boilers at a distance.

Mr. F. Young said the design described by Mr. Carrington was patented by Mr. Chanter in 1834. He thought Mr. Rumble's furnace would prove efficacious if sufficient room was provided to produce slow combustion. He agreed with Mr. Louch that Mr. Williams had thrown great light on the use of coal and the prevention of smoke. He did not think Juke's furnaces were always efficient, as he had frequently seen smoke issuing from the chimney of the works that supplied the fountains in Trafalgar Square with water, and here Juke's furnace was in use.

The Chairman, in closing the discussion, observed that it was such an important subject that he hoped some member would prepare a paper, and bring the question again before the society, so that the discussion might be renewed.

June 2nd, 1862.

E. RILEY IN THE CHAIR.

ON MARINE GOVERNORS.

BY LEWIS OLRICK.

The author having shortly recapitulated the theory of a governor, proceeded to give the history of the gradual introduction of marine governors, and mentioned the different governors brought more prominently before the public, and pointed out their merits and demerits, according to his experience.

The first governor ever invented for regulating the speed of steam engines was protected by an English patent, in 1784, by James Watt, and this invention has been used up to the present date in almost the same shape as Watt gave it to us (see Fig. 2). This is the common, centrifugal or conical pendulum governor, which consists of two equal and similar revolving pendulums, turning about a vertical axis, which is driven by belts or gearing from the crank shaft of the engine. The only difference between this governor and a common pendulum is that the pendulums in the governor revolve round its axis in a circular horizontal plane, and the common pendulum vibrates backwards and forwards in a vertical plane. They are, however, both subject to the same laws of nature, and must be calculated in the same manner.

The length of a pendulum vibrating seconds in London is 39·1393in. The vibrations of pendulums are as the square roots of their lengths; thus, to find the length of a pendulum for any given number of vibrations in a minute, we get—

When n = number of vibrations in a minute.
l = length of the pendulum required.

$$n : 60 = \sqrt{39{\cdot}1393} : \sqrt{l}.$$

and
$$\frac{\sqrt{39{\cdot}1393} \times 60}{n} = \sqrt{l}.$$

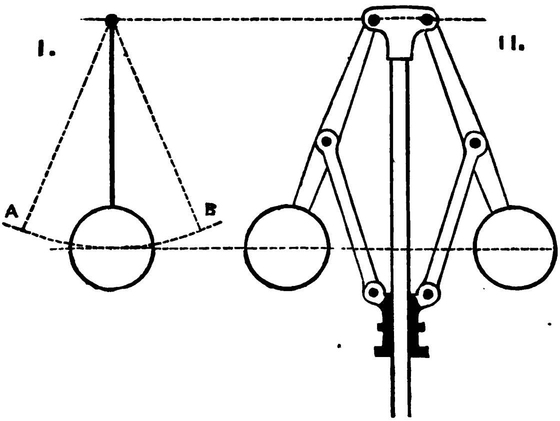
For instance, if we want to know the length of a pendulum that will make eighty vibrations in a minute, then we get in the same way—

$$80 : 60 = \sqrt{39{\cdot}1393} : \sqrt{l}.$$

$$\text{and } \frac{\sqrt{39{\cdot}1393} \times 60}{80} = 4{\cdot}692 = \sqrt{l}.$$

Consequently, $l = 4{\cdot}692^2 = 22{\cdot}015$in.

The length of the pendulum corresponds exactly with the vertical height h of the governor. Thus, for every vibration from a to b and back



again, to a, the governor makes a whole revolution (see Figs. 1 and 2.)

We thus see that if the vertical height of a governor is equal to 39·1393in., the governor will make exactly thirty revolutions.

From the above we get the following formulæ* for calculating the main points in a two-ball governor.

Calling h = the vertical distance between the point of suspension and the plane of revolution of the centre of balls in inches,

r = revolutions per minute,

l = length of arms in inches from point of suspension to centre of ball,

* These formulæ appeared a short while ago in a letter addressed by the author to the Editor of *The Engineer*.

d = diameter in inches of circle in which the centre of balls revolve,

$s = \frac{d}{2}$ = radius in inches of the same circle.

$$\sqrt{39 \cdot 1393} \times 30 = 187 \cdot 68;$$

then we get $r = \frac{187 \cdot 68}{\sqrt{h}}$

$$h = \left(\frac{187 \cdot 58}{r}\right)^2$$

$$h = 2\sqrt{l^2 - h^2}$$

$$s = \sqrt{l^2 - h^2}$$

$$l = \sqrt{h^2 + s^2}$$

In the application of governors for steam engines we must always bear in mind the entirely different circumstances under which a land engine governor and a marine governor work. But although they work under different circumstances, caused by the one working on land and the other on board ship, still there is one main point which the author called particular attention to, as it must never be lost sight of in designing and constructing a governor, and this point is common for land and marine governors, viz., "*always to maintain two constantly acting forces opposing each other.*" Unless this condition is fulfilled in the apparatus the author maintained it was *no* governor.

In the case of land engines it must be remembered that there is always a heavy fly-wheel attached to the shaft for regulating the speed of the engine, by receiving the power suddenly exerted and storing it up, only to pay it out again in the next moment, when the resistance at once is increased beyond the average. The fly-wheel is by itself a regulator, but as it only removes minor irregularities, and does not confine the engine within a certain number of revolutions—as the speed of the fly-wheel might be increased almost infinitely—a different medium is therefore required to regulate the engine more correctly. This is found in Watt's governor. From the fact, however, that the fly-wheel, with its heavy rim, resists any sudden alteration in speed on account of its inertia, and the same being the case with the balls of the governor,

it will easily be perceived that this governor will not act instantaneously—as, for instance, Siemens' single pendulum governor does—but for all practical purposes it is generally sufficient, and hence its universal application.

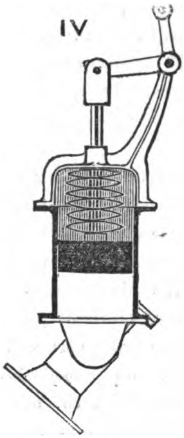
The two constantly acting and opposing forces are in this case, the centrifugal force and the centripetal force (or force of gravity) the latter one making it necessary always to give the axis of the governor a fixed vertical position, otherwise the force of gravity will be inactive.

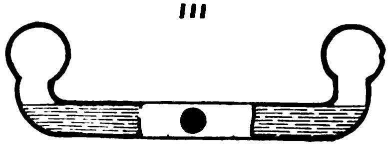
Having mentioned the land governor as much as necessary for the purpose of this paper, the author passed over to marine governors, and pointed out the main features which constitute a marine governor, as follows:—

In the first instance, as mentioned above, two constantly acting forces opposing each other, must always be maintained; secondly, the governor must not be affected by change of position, from the pitching of the ship in a rough sea way, as it would otherwise work the throttle valve at times when it was not required to do so, and on the other hand, neglect to do it when it ought to; thirdly, it should as much as possible work without fricton, as the sensitiveness of the governor else, will be considerably impaired; next, its action ought to be instantaneous, considering the sudden jerks and the violence with which the engines often fly round, on account of the sudden disappearance of nearly all the resistance, and having no heavy fly-wheel that would resist the sudden start or racing of the engines, and store up the power now uselessly expended. It is for such cases that we ought to provide, and consequently this point is rather important, as the instantaneous shutting of the valve might often save a break down in the engine room, which otherwise might be fatal to the ship. But equally important to this is the instantaneous opening of the valve, as the engines else might be brought to a standstill before the steam was again admitted after once shut off.

When it was found necessary to adopt some means for regulating the speed of marine engines the common two-ball governor was first applied, but it was soon found to be very defective in its action; and it being affected by change of position, from the pitching of the ship in a rough sea, it is clear, from the pendulous nature of the common governor, that it would not act properly on account of the motion of the vessel. (It

was here shown by a model how the balls would work the sliding sleeve when the governor was tossed up and down, as in a ship pitching in a rough sea.) Hence various schemes have been proposed as a substitute for the common two-ball governor, amongst them one using a float or swimmer (as used in ordinary land boilers) outside the ship, intending to open or shut the throttle valve according to the height of the water;





the incompleteness of this apparatus caused it to be very quickly abandoned. Another method was a hollow tube partly filled with mercury (Fig. 3). The pitching of the ship caused the mercury to flow either to one or the other end of the tube, and thus opening or shutting the valve, simply on account of the weight of mercury depressing either end, as the case may be. The tube was placed lengthways in the ship, and quite horizontally, so as to have the mercury balanced when the ship was in a calm sea. This invention, as well as the next mentioned—the single pendulum governor—failed, although theoretically correct, on account of the irregular action of the waves on the movements of the ship. For instance, it happens often in a following sea that, although the stern of the ship is down, still the greatest part of the screw is out of water, and *vice versâ*. The consequence of the screw being pitched out of the water is, of course, that the engines race or fly

round at a very great velocity—sometimes even at the rate of double the number of revolutions, compared with the usual speed. It will thus be seen that these two kinds of governors cannot be depended upon, as they often open the valve in full where they ought to shut it, and *vice versâ*.

The single pendulum governor consists only of a suspended pendulum, which is at liberty to move in a plane, parallel to the keelson of the ship, and thus its action is only dependent on the pitching of the vessel, which, as shown above, is not satisfactory. The rolling of the ship has no effect upon it whatever.

Another invention, which might be called the hydrostatic governor (Fig. 4), is correct in principle, but its introduction has been prevented by several practical difficulties. It consists of one or two cylinders, placed at or near the stern of the vessel, in a line with the shaft, one end of the cylinder being in direct communication with the sea by means of a Kingston valve, the other end being left quite open. The action of the governor is as follows:—When the water partly leaves the stern the spring applied on the top of the piston forces the piston down, and at the same time closes the valve; and, on the contrary, when the stern is deeply immersed, the water forces the piston upwards against the pressure of the spring, and thus opens the valve in full. One of the principal objections to this instrument is the necessity of cutting one or two holes in the side of the ship, as it could hardly be expected that a shipowner would go to the expense of docking his ship for the sake of introducing a governor; it must, therefore, either be applied to a new ship, or wait till a necessity occurs for docking the ship.

The above-mentioned instruments, except the common two-ball governor, all belong to a class of regulators which work entirely independent of the engine; and perhaps that is the main reason why they have not given satisfaction pratically, as, according to the author's opinion, nothing but what will follow the movements of the engine very minutely will be efficient or able to do its work properly.

The kind of governors next described differs in this respect from the former, they being all driven direct from the screw-shaft by means of gearing, belt, or rope

The oldest of this kind of marine governors was invented by the

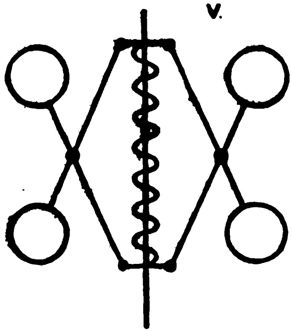
elder Brunel in 1822. After the common two-ball governor was first found very defective in its action in ships, on account of its being affected by the pitching of the vessel, it was made use of by substituting the spiral spring for the force of gravity, and by extending the links beyond the arms of the common governor, and applying balls at the ends of these new arms (Fig. 5). The object of this arrangement was to form a balanced governor, but the inventor did not succeed in gaining this point, as the practical application of it proved to the contrary, for the pitching of the ship had the same effect upon it as upon the common two-ball governor. (It was shown by a model how this instrument was affected by being tossed up and down like a ship pitching in a rough sea.) This governor was fitted to the Great Eastern, but since taken out again and replaced by one of Silver's balanced four-ball governors.

It need hardly be said that several parties have tried the common two-ball governor (See Figs. 6 and 7), substituting a spiral spring for the force of gravity, which was lost by placing the instrument horizontally; the pitching of the ship, however, affected the action of the instrument so seriously at the time when it was most wanted that it was soon abandoned.

The principal cause of this defect in the instrument is easily accounted for by the governor not being balanced, in which case it would not be affected in any way by the motion of the ship. The latest application of a two-ball governor, which is identical in principle with the last illustration (Fig. 7), is Porter's governor (Fig. 8), which has been patented in this country under another name. (The liability of this instrument to be effected by the pitching of a vessel was illustrated by a model.)

The first governor which was balanced was invented by Mr. Silver, it (Fig. 9) had only one arm, extending equally on each side of the spindle, with a heavy ball on either end. When at rest the spring forces the arm in the same direction as the spindle, but being set to work the centrifugal force drives the balls out and tends to place the arm at a right angle with the spindle. Thus far the instrument is right enough as a governor; but the fact that the balls when in motion continue rotating in the same plane, while the spindle alters its posi-

V.



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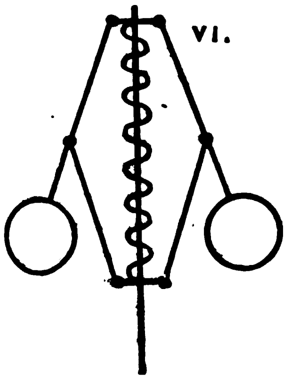

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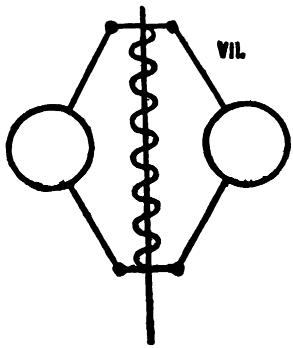
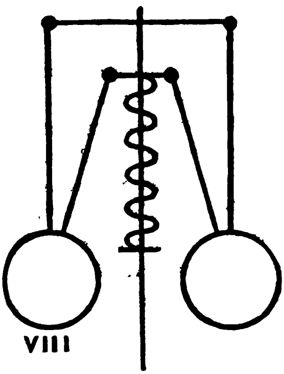
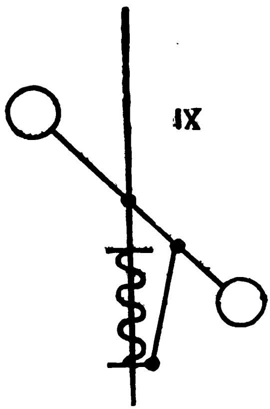




VIII

IX

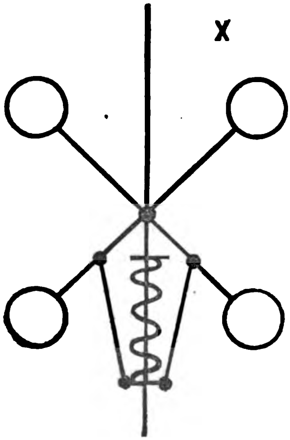


tion, makes it unfit for marine purposes, because by any alteration in the position of the spindle the governor will work the throttle valve without any reference to the change of speed of the engine; hence the necessity of adding another arm to balance the first one, each correcting the other one's motion. This improvement perfected the governor thus far that any variation of speed of the engine was followed by a change in position of the throttle valve. This was the first practically balanced marine governor so well known amongst marine engineers as "Silver's four-ball governor" (Figs. 10 and 11). Being entirely balanced the pitching of the vessel has no effect whatever upon it, either placed vertically or horizontally, the latter position, however, being the one usually adopted.

The great difference between this governor and Brunel's is that the last one, placed vertically, is still a governor without a spring, although not a marine governor, whereas Silver's is no governor at all without a spring.

Although the difficulty of making it perfectly balanced had been overcome in this governor, and it was thus far completed, another difficulty, not thought of before, arose. When the racing of the engines is very abrupt the inertia of the balls of the governor resists the sudden start, and causes the gearing to break or the band to slip on the pulley at times when a perfect action is most required, and in either case failing to shut the valve at the moment it ought to be done. This is the principal objection to this otherwise perfect marine governor. In later instruments, invented by the same gentleman, this difficulty has been avoided. The first of these is the well-known "fly-wheel governor," in which the balls are replaced by a fly-wheel turning loosely on the spindle within limits (Fig. 12.) By this arrangement the inertia of the fly-wheel will resist any sudden change in speed, and thus allow the spindle to turn in advance of the main or heavy portion of the instrument, and by its direct connection with the throttle valve, close the latter to whatever extent the nature of the case may require, the inertia or retarding tendency of the body or heavy part of the instrument being in this case, by resisting the sudden start of the engine, the direct and efficient cause of action; and we shall thus find that the inertia of the heavy part, which in the four-ball governor

X



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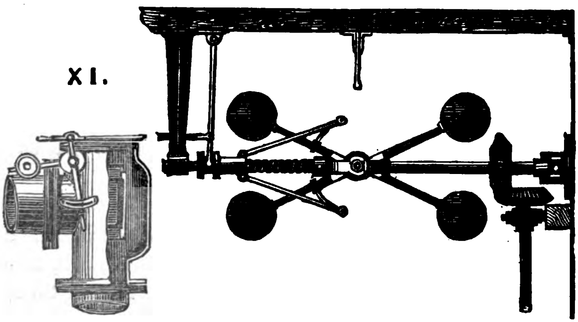

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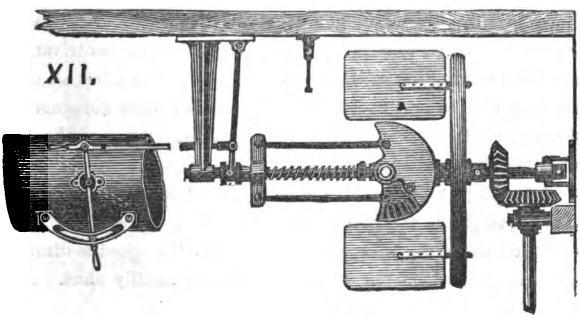
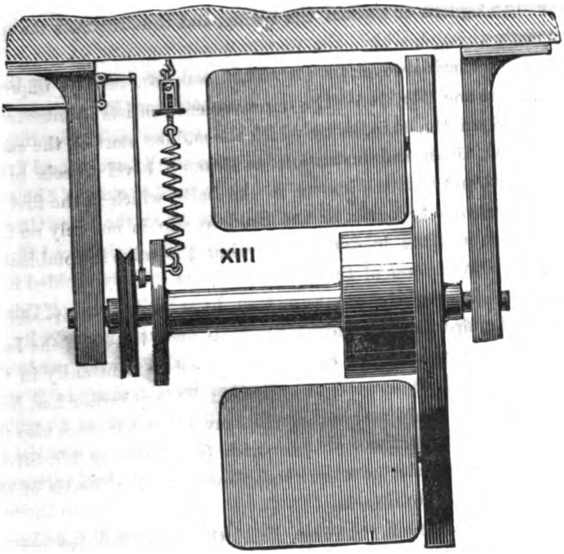


was a fault or vice, becomes in this governor a virtue. The momentum of the fly-wheel in combination with the force of the spiral spring are the means through which the instantaneous opening of the valve is attained. Various means have been adopted for transmitting the differential speed of the spindle to the fly-wheel, but in the case before us the motion is usually given to the wheel by the use of a spring, and through the means of two quadrants and a small bevel wheel fixed to the fly-wheel. It will thus be seen that any sudden start of the engine acts instantaneously on the valve and shuts it, at the same time that all the force of the sudden jerk is taken up by the spring, and thus the breaking of gearing and slipping of the belt is entirely avoided in this instrument. The spring being thus loaded gradually gives off this load partly to the fly-wheel by endeavouring to increase its velocity, and partly to opening the valve again. The wheel, however, needs some means of limiting its speed and balancing its *vis viva*, as it would otherwise run anyhow, and lose entirely all its power as a regulator. This is acquired by placing four fans of a suitable size in a radial position to the spindle. As now the *vis viva* of the fly-wheel increases as the square of the velocity, and the resistance of the fans to the atmosphere also increases as the square of the velocity, it will thus be seen that those two forces balance each other.

The difference between the fly-wheel governor and the four-ball governor is, that the last one limits the position of the throttle valve *directly* by keeping its position according to the centrifugal force, whereas the fly-wheel governor does it *indirectly* by limiting the speed of the fly-wheel by using the fans.

Since this first fly-wheel governor was introduced Mr. Silver has made several others, differing only in the mechanical contrivances for transmitting the motion of the spindle to the fly-wheel, but all of them maintaining the features necessary for a perfect marine governor. The one illustrated by Fig. 13 is, however, superior to any of the others, because it is here within the power of the engineer to regulate the speed of the engine under full speed, by either tightening up or slackening the spring. In the first case the speed is increased by the spring keeping the valve more open, and in the latter the speed is diminished by the spring allowing the valve to be more readily shut. All the



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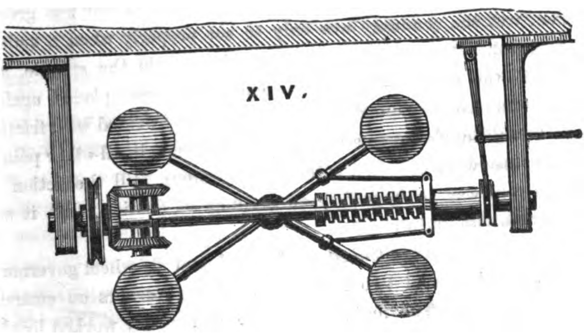


XIV.

other governors must be thrown out of gear and stopped before the engineer can tighten or slacken the spring, and thus regulate the speed of the engine.

The next marine governor mentioned was Mr. Silver's improved four-ball governor (Fig. 14.) The improvement consists in introducing a loose pulley on the spindle, by which the sudden start of the engine is transferred direct and instantaneous through bevel wheels to the throttle valve, and thus the inertia of the balls, which in the first one caused the gearing to break or the band to slip, is not only no fault here, but even a virtue in assisting to shut the valve in combination with the centrifugal force of the balls.

Other similar combinations have been used by Mr. Silver—for instance, the combination of centrifugal force and the inertia of the balls, resisted by a spring, in which case the balls rotate constantly in the same plane, at right angles with the spindle. This governor has, however, only two balls. The patent for this invention combines also the use of a fly-wheel. Another governor with four balls, by Mr. Silver, contains the combination of centrifugal force and the inertia of the fly-wheel in resistance to a spring.

All of these governors, however, fulfil the conditions for perfect marine governors, pointed out at the commencement of this paper, and they have been largely introduced in the mercantile navy of this country. One fly-wheel governor, patented in 1857, was soon abandoned on account of the amount of friction to be overcome in working it, and consequently the sensitiveness of the instrument was greatly impaired, and the tendency was only to act properly when a sudden start occurred. It consisted of a fly-wheel loose on the spindle, and attached to the fly-wheel were two inclined V-shaped planes, against which worked two corresponding inclined planes, provided with friction rollers; but although it was a true marine governor in all other points, and the planes were supplied with friction rollers, still the action of the instrument was so imperfect, on account of friction, that it was not thought advisable to apply it.

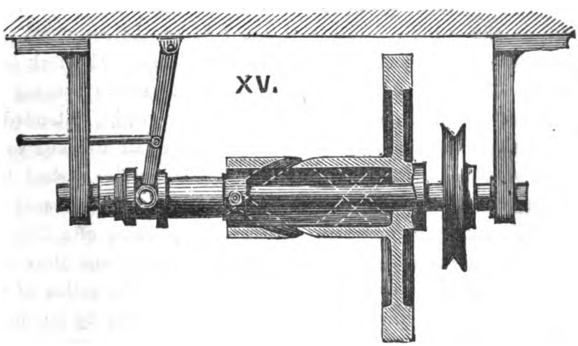
Besides the above-mentioned centrifugal and fly-wheel governors, Mr. Silver has invented two kinds of marine governors on entirely different principles. The first kind consists of a pulley worked by the

large engine, and turning loose on the spindle of the governor. On this spindle is fixed a cylindrical boss, provided with spiral grooves, by which means the throttle valve is worked. At the end of the spindle is a fly-wheel and a crank, which is worked by a small steam cylinder. It is by this small cylinder that the speed of the large engine is regulated, because as soon as the large one overruns the speed of the small one, the valve is immediately shut by the spiral groove forcing the sleeve back, and *vice versâ*. Another modification on exactly the same principle has also been patented by Mr. Silver, and differs only from the former in the mode of working the throttle valve. Thus it will be seen that the large engines can be regulated to any speed by the mere turning of the cock admitting steam to the small cylinder.

The second kind of governor is the so-called "pulsating governor." It consists of a common conical valve, placed in the steam-pipe in such a manner that the pressure and velocity of the steam entering the cylinder tend to shut it, and the spring on the reverse side tends to open it again. As the speed of the engine increases the valve closes more and more, and *vice versâ*, and thus effects the regulation of the engine.

During the last two years several other governors have been introduced.

The first one is a fly-wheel governor invented by Mr. Meriton



(Fig. 15.) It consists of a fly-wheel to which is attached a small cylin-

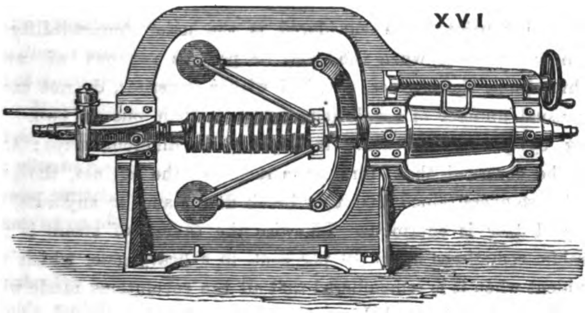
drical boss with two spiral grooves cut one in each side, and in these grooves work two studs fixed on one end of the sliding sleeve, which follows the movement of the spindle, driven, as usually, by a band from the screw shaft. Now as the fly-wheel is allowed to turn loose on the spindle, so as to act by its inertia, any sudden start of the engine will immediately shut the valve, and thereby carry the studs to the farthest end of the groove. When once arrived there it would require some contrivance to replace them in their first position, and thereby open the valve again; but this is left out in this governor, and thus it will be seen that the inventor has left out one of the main points so essential in governors, viz., always to maintain two constantly acting forces opposing each other. Another point which has been mentioned before has been omitted in this instrument, viz., a counterbalance to the *vis viva* in the fly-wheel, because if there is not a resistance that increases equally as much as the *vis viva* of the fly-wheel does, the fly-wheel can be made to increase its speed anyhow by a gradually increasing force, and thus the governor loses all its regulating power, because the throttle valve remains open, although it ought to be shut.

The next instrument described was Miller and Knill's governor. It consists of a fly-wheel, to which is attached one-half of a cylindrical boss; the other half of this boss, which also forms the sliding sleeve, is allowed to move longitudinally on the spindle, but follows its rotating motion, whereas the fly-wheel with the first half of the boss is loose on the spindle. The boss is cut in two halves at an angle of about 60 degrees to the direction of the spindle. The fork lever, which is worked by the sliding sleeve for the purpose of opening and shutting the throttle valve, is provided with a weight, intended to force the one-half of the boss up against the other half attached to the fly-wheel, so as to replace it in its first position, when pushed back by the action of the governor. The objection to the application of any weights for such a purpose as this, is, that the pitching of a ship will often interfere with the force of gravity of the weight, and thus open the valve when it ought to be shut, and *vice versâ*. The action of this instrument is the following:—As the fly-wheel resists by its inertia any sudden change of motion, the one half of the boss will be forced back by the other half attached to the fly-wheel, and thereby cause the

valve to be shut; it is afterwards opened again by the weight. This is the case when any sudden starts occur, but when the increase of speed is gradual the weight on the fork-lever will press those two slanting surfaces of the boss together, and thus fail to shut the valve when it ought to. In this governor a counterbalance to the *vis viva* of the fly-wheel has also been omitted, and thus the regulating power of the instrument is greatly impaired by being at times allowed to run away anyhow.

A governor lately introduced is Porter's, illustrated by Fig. 16.

XVI



This instrument is simply a common two-ball governor, placed horizontally, with the links turned upwards instead of, as usually, downwards, and provided with a spring as a substitute for the force of gravity resisting or balancing the centrifugal action of the balls. Being a two ball-governor, and not in any way balanced, it will, to a certain extent, be affected by the pitching of the ship, and thus its true action as a governor be impaired. Another fault in this governor is the inertia of the balls resisting any sudden start of engines, and thus causing the gearing to break or the band to slip at times when most required, and in either case, failing to shut the valve as promptly as it ought to prevent the engines from racing. This objection becomes more serious with a governor that is intended to run at the rate of 300 to 400 revolutions per minute.

After having mentioned the different governors that had come under the author's notice, he finally called attention to the benefits to

be derived from the application of a perfect marine governor in a ship, as follows:—

In the first instance, it allows the engineer, in a gale of wind and a rough sea, to attend properly to the working of his engines, which he must necessarily neglect if he is obliged to stand by the throttle valve, without being able to move from his post, as he might otherwise cause a break-down; and, though he may try and do his best, it is impossible for him to shut off and open the valve as promptly as the governor does it, in fact it only allows so much steam into the cylinder as can be usefully applied by the engine.

The next point to be considered is the utter impossibility for the engines to race when the screw or paddles get out of water, at which times the engines, supplied with a governor, do not exceed their usual number of revolutions by more than one or two. The saving by preventing racing is acquired in different ways; thus, it will be observed that, during the racing of the engines, the parts are often so overstrained that they break down, and, at any rate, the wear and tear is enormous. Likewise the saving of steam is considerable, sometimes about 10 per cent. in a heavy gale, which will be evident when it is remembered that all the revolutions made while the engines are racing and the screw out of water are merely a waste of steam, as they do not propel the ship.

All these evils can easily be avoided by applying a perfect marine governor, the cost of which will be repaid to the owner of steam-ships in less than six months by the decrease in his coal bill, and his bill for repairs in the engine-room, and likewise by saving of time in which the ship will make its voyage.

As a proof of the correctness of this last assertion, the author mentioned the Tasmanian, belonging to the Royal Mail Packet Com pany. This screw steamer has often been obliged to lay to in a heavy gale, for fear of breaking her machinery on account of racing, but since she was fitted with one of "Silver's fly-wheel governors," she has been able to continue her voyage undisturbed, as the engine maintained almost the same number of revolutions, whether the screw was out of water or deeply immersed. Many similar cases have come under the author's notice in regard to other ships, where a couple

of days have been saved on a voyage of ten to eleven days' duration in a heavy gale of wind, by the application of a properly-constructed marine governor.

September 1*st*, 1862.

E. RILEY IN THE CHAIR.

ON MARINE GOVERNORS.

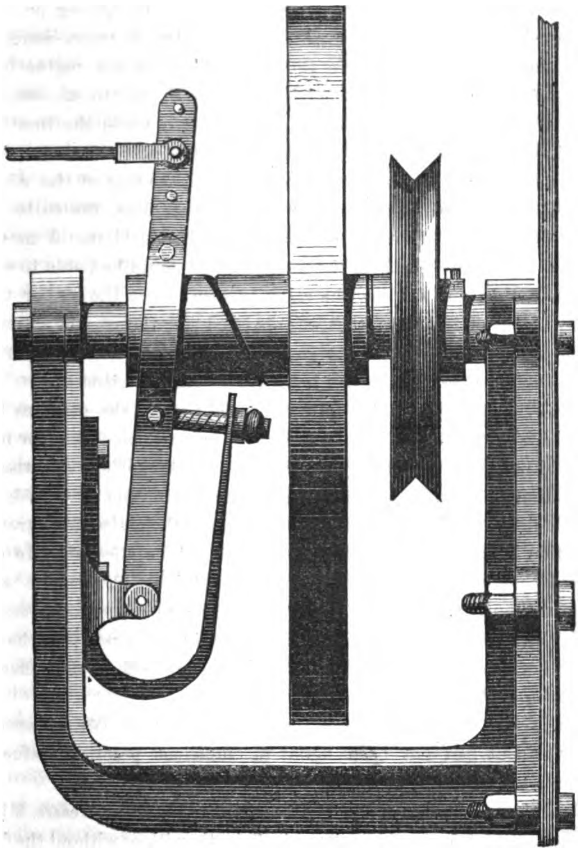
By LEWIS OLRICK.

DISCUSSION.

Mr. Perry F. Nursey opened the discussion by assuming Mr. Olrick's data to be correct, from which it appeared the main features of a marine governor were the maintenance of two constantly acting forces opposing each other, the absence of all influence upon the governor from the varying position of the vessel—the reduction of friction to a minimum to ensure the sensitiveness of the apparatus, and instantaneous action upon the throttle valve both in closing and opening it. But in designing a machine to effect these objects, he observed, there were other and equally important considerations to be kept in view, viz: simplicity and economy of construction. It was essential also that the engineer should be able to regulate the speed at which the valve was to be opened by the governor. Complex machines might do their work well, but were more liable to derangement than those of a simpler character. The former were open to the further objection of increase in first cost and maintenance, whilst the latter secured opposite results. The chief objection to Silver's four-ball governor (No. 11) was, that the balls did not expand sufficiently quick, therefore the instantaneous action was absent. No. 12 appeared designed to remedy that defect, but was more complicated; and, notwithstanding the theory of the necessity of affixing vanes to the fly-wheel, practice had evidenced their inutility. If they were not necessary on Meriton's, or on Miller and Knill's, why were they required on Silver's fly-wheel? Although occupying a large space in the engine-room, the governor appeared to be

a very effective one, but was expensive and liable to damage by sudden strains, by which the tooth-wheels and sectors might be injured by stripping. No. 13 appeared to be a very good governor; but the principles of its action being boxed up from sight, an opinion of its practical value could not readily be formed. In No. 14, Mr. Silver appeared to have combined the action of Nos. 11 and 12 with the intention of allowing the valve to be instantly closed, but retarding the opening of it, as explained by Mr. Olrick, but it did not appear to be in the power of the engineer to regulate the speed with which the valve should open. The next apparatus described as being worked by the differential action of a fly-wheel, and a small steam engine in connection with the main engine seemed a good arrangement, but carried with it the disadvantage of being complicated and expensive. In Mr. Olrick's description of Meriton's governor (No. 15) he seemed to have fallen into an error respecting the opening of the valve. Supposing the machine to be in connection with the engine, and running at the same speed with it, and the studs being at one end of the screw-ways and the throttle valve open, any excess of speed on the engine would immediately act on the studs and cause them to slide in the screw-ways, thereby closing the valve, the steam being then shut off, and the speed of the engine and spindle of governor having been consequently reduced, and the momentum of the wheel continuing, the screw-ways then acted upon the studs and returned the sliding-collar to its original position, thereby opening the valve. There however, appeared to be the same defect in this as in Silver's No. 12, viz: the sliding-collar being geared to the wheel by means of the screw-ways and studs, there were no means of regulating the speed at which the throttle valve should open. It might, and indeed did, act instantaneously in closing the valve, but did the like in opening it. Miller and Knill's governor had been imperfectly described by Mr. Olrick. In the diagram which Mr. Nursey exhibited *(See opposite page)*, A was the momentum-wheel, the boss of which was formed with an inclined face on one side and a stop on the other; B was the shaft on which the wheel was loosely fitted; C was a sliding-collar which worked on a feather on the shaft B, and acted on the lever D, from whence the connection was taken to the throttle valve. The spring E was for the purpose of returning the lever

and connections to their original position and opening the throttle valve. An important feature in this invention was the arrangement of stops, which Mr. Olrick appeared to have misunderstood. By the stops the motion of the fly-wheel was controlled, which control was obtained by forming a stop F on the boss of the fly-wheel equal to a quarter of the



area of the face of the boss, and also a stop G of similar proportions on the face of the driving pulley at H, which was keyed on to the shaft B, by which the wheel was free to turn to the extent of half a revolution, and also admitted of its acting on whichever side of the inclined boss and collar it might be set to act on, but confining its action to that side only, and the apparatus was adapted to either a right or a left handed engine, according to the position in which the driving pulley H was keyed on to the shaft, for which purpose two keyways were cut. The action of the apparatus was thus:—Motion from the engine being communicated to it through the driving pulley H, on any accession of speed, the motion of the shaft became accelerated while the inertia of the wheel remaining the same, allowed the shaft to perform a partial revolution through its centre, and, by means of the face of the sliding collar acting on one side of the face of the wheel boss, the collar was forced backwards. The action of the stops F and G would now be seen, as, were it not for them the inclined faces would be liable to override each other, and so allow the valve to open before the proper time, but by means of the stops, that was obviated and the correct action of the apparatus ensured. These governors had been fitted in various vessels, and the best results had in all cases been experienced.

Mr. F. C. Reynolds said it appeared to him from the diagram that although Miller and Knill's governor might be an efficient one for most practical purposes, it certainly was not a perfect one, for this reason, that although upon sudden acceleration or diminution of speed, the throttle valve would be shut or opened, nevertheless with a gradual alteration in speed the throttle valve would not be affected. He considered that a perfect marine governor must keep the engine at a uniform definite speed. And if it was desired to prevent the engine getting any gradual alteration in speed, a marine governor must have a fan or something equivalent thereto, that would afford an increased resistance as the speed increased.

Mr. Louch stated that vanes had been tried on Mr. Meriton's governor, but had not been found of sufficient practical value to warrant their use.

Mr. Glynn said it had not been clearly stated whether Messrs. Miller and Knill's governor would work most efficiently with or without the fans.

Mr. C. L. Light did not think the fans an advantage, as they acted by displacement of the atmosphere, and the only way to retard the velocity would be by so arranging the fans as to present an area increasing in the same ratio as the speed accelerated.

Mr. R. G. M. Smith had no doubt that the spring in Miller and Knill's governor would open the valve, but considered it insufficient to work it practically. With reference to the fans he considered the differential velocity was much greater with than without them. The acceleration of speed would, in a ship like the Great Eastern, perhaps be only decimal upon the velocity of the engine. If the governor could not regulate an increase of revolutions it would take up the velocity of the ship. In short vessels the action being violent would be correct.

Mr. Miller said that his governor could be regulated to open quickly or slowly according to whether there was a stern or head wind, and would work efficiently in any ship, no matter how large. But as far as the efficiency of the governor was concerned the action was quite as true by a proper weight in the fly wheel as by fans, all that was required was a sufficient weight to prevent any additional speed on the engine. The form of spring used by him was adjusted to regulate the action of the valve, to suit the quick or slow motion of the ship as required.

Mr. F. Young observed with reference to the sensitiveness of governors, he had made some experiments with Silvers' governors, and found that if the engine was calculated for say 80 strokes per minute, and it fell one revolution short the throttle opened. If the revolutions were exceeded by one the throttle was closed. No marine governor equalled that of Silver's latest arrangement.

Mr. Olrick, in reply, said he knew when he thought of preparing his paper that it was upon a very difficult question, and a subject of much litigation, therefore, he determined to write a paper that would be impartial and exhibit all kinds of governors, with the view of exchanging opinions. In answer to Mr. Nursey's remarks, which came entirely under the head of mechanical arrangement, all he (Mr. Olrick) could say was that if one governor was carried out according to a certain mechanical arrangement you could patent that arrangement,

and another arrangement could be as easily patented; but these were points which lawyers had to decide. He would merely go into the question scientifically, and the opinion he gave was the result of five years' experience on board ships, both with and without governors. He thought there was no stability with regard to the remarks that had been made about cheapness, for every one would admit that although a Dutch clock was much cheaper than a chronometer, no one who wished a good timekeeper would prefer the former for the latter. It was not the question whether one governor cost £5 or £20 less or more than another governor, the question was what results would be achieved by its employment. Mr. Lamb, the manager of the Peninsular and Oriental Company, estimated that a governor which cost, say £170, paid for itself in less than six months, and that was only the saving it effected in the coal bill, and wear and tear on the machinery, without reckoning all the saving in time effected by the vessel going through the water at full speed. Mr. Nursey made a remark about No. 11, that it was not sufficiently quick. Now that was perfectly true, but if Mr. Nursey had read his paper carefully, he would have seen that he, (Mr. Olrick) pointed out this fault. It was in consequence of this fault that Mr. Silver had another arrangement, called the fly-wheel governor, which was similar to that referred to by Mr. Reynolds. He could mention a governor (one of Silver's fly wheel governors) that had been fitted in a ship and not used for some time, simply because the engineer was averse to the use of patent inventions, although the engine would sometimes make 120 to 130 revolutions, the usual number being 75. Subsequently, however, the second engineer was appointed chief engineer, the governor was applied, and the consequence was that in a gale of wind the engine never exceeded 76 revolutions, and considerable time was saved by the use of the governor. Another case he might cite was that of the "Royal Charter," which was lost on account of racing. But there was another steamer of 100 horse power, which fortunately had a governor, and she came safely into Liverpool. So that there could be no doubt the little ship was saved by having a governor while the large one was lost through not having one. He then gave the mathematical demonstration for the necessity of fans.

With respect to Mr. Nursey's remark about the No. 12 governor being liable to derangement on account of the toothed wheels being exposed, and his objection that in No. 13 the wheels were boxed up, he, (Mr. Olrick) thought it was apparently a tendency to find fault without any real cause, as no accident of that description had ever come to his knowledge, although 185 of that description of governor had been applied. One single case had occurred where the teeth broke, but this was explained by the fact that the engineer had not properly readjusted it, after he had had it disconnected This occurred in either the "Brigadier," or the "Life Guard." While referring to those ships he might mention another thing. It had been stated that Mr. Silver's governor had been found useless, the proof of which was that it had been taken out of the vessel. But the reason why it was taken out was because it was more required in another ship, and into the smaller ship where it was not so much required, Messrs. Miller and Knill put one of their governors. He next came to Mr. Nursey's remark about the model with stops and without stops. He, Mr. Olrick, thought the stops were useless. Mr. Olrick maintained that it was the momentum of the wheel that opened the valve, and the inertia that closed it. He agreed with Mr. Smith that without fans the speed of the engine could be increased to any extent without having any effect whatever upon the valve. With respect to the adjusting of the spring in Miller and Knill's governor for long and short seas, he thought that this arrangement did not meet the requirements of a perfect marine governor. In conclusion, he would only say that the object he had in view in reading the paper was to lay before the meeting what information he possessed with regard to marine governors, but very little known among engineers, and one that required some study and a great deal of practical experience before it was thoroughly understood, and thought it was a subject that should be impartially discussed, as each member would be mutually benefited, and at the same time good done to the socieiy to which they had the honour to belong.

The Chairman said that there had been a great diversity of opinion as to the merits of the different governors. There were no doubt special merits in some in which others were deficient.

October 6th, 1862.

E. RILEY IN THE CHAIR.

ON STEAM CARRIAGES.

By Mr. A. F. Yarrow.

The application of steam to the propulsion of carriages on common roads is by no means novel, for it was tried, and to a considerable extent, proved successful, some thirty years ago. It appears, however, from the great opposition at its introduction, to have been allowed to remain dormant for some time, for we find no experiments worthy of notice have been tried until very recently. However, from what is being done in various parts of this country, it may fairly be concluded that a move is about to be made in this direction.

The author said in treating this subject he did not intend tracing the history of steam carriages up to the present day, or recording all the patents that have been taken out, but should confine himself merely to such as embody any new principle, or would aid in any way to form opinions on the various points to be considered. It is hardly necessary to add that traction engines could not be included, as, owing to their speed being slow, and having to draw and not carry, the circumstances are so materially altered as to render it absolutely necessary to devote another evening to their consideration.

He then referred to what was done in former years by the various engineers of the time, and commenced with James' steam carriage.

Mr. W. H. James took out a patent in the year 1824 for improvements in steam carriages, and several were constructed on his plan. The peculiarity of it was that he employed four cylinders, each pair being coupled on to one driving wheel, the axle being divided in the centre. The object of this was to render each wheel independent of the other, to obviate the necessity of throwing the inner one out of gear when turning curves, and at the same time for both to be always drawing. The motion of the springs was allowed for by making the engines and the frame, in immediate connection with them,

vibrate upon hollow axles provided with stuffing boxes constituting the steam and exhaust passages. These hollow axles were fixed to the main framing of the carriage, while the crank shaft moved up and down with the wheels. A few experiments were tried with these carriages, and it has been said that they attained a speed of twenty miles an hour, but owing to the complication of the engines and the difficulty of obtaining a suitable boiler, they were far from being successful, and were soon abandoned.

The principle of having four cylinders, one pair driving each wheel independently of the other, has been more recently adopted in one of Bray's traction engines, but the advantage gained was not found to compensate for the extra expense and wear and tear.

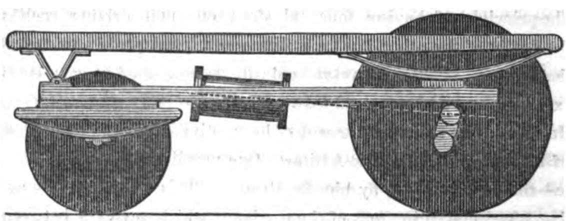
He then noticed an arrangement of locomotive carriage patented at the end of 1826 by Mr. Frederick Andrew. One peculiarity is worthy of special notice—the mode adopted by him for steering. This was effected by a simple steering wheel placed in front of the carriage, which revolves between two lateral bars of a framing, which is a continuation of the under carriage or wheel plate. By guiding this wheel by means of a lever—which can easily be done as there is but little weight on it—the direction of the two fore wheels which guide the carriage can be altered. So great is the command that this simple and effective arrangement gives over the movements of the carriage that it was adopted by Mr. Gurney, and still more recently by Mr. Aveling in his portable locomotive engine. Another novelty introduced by this inventor was the use of oscillating cylinders, acting direct on the crank shaft, and placed in a horizontal position, so that they remained quite unaffected by the motion of the springs. This carriage, like many of the others, proved unsuccessful, owing to the failure of the boiler.

The next experimentalist worthy of notice is one who attracted considerable attention at the time—possibly more than any other, viz., Goldsworthy Gurney, who, being liberally supported by Sir Charles Dance and several other capitalists, built a number of steam coaches, and, after repeated trials and failures, succeeded in establishing a line between Cheltenham and Gloucester.

Mr. Gurney, like many others, commenced by resorting to the agency of moveable legs striking out behind, in order to obtain the necessary adhesion. A little experience demonstrated the uselessness of them, and they were abandoned in favour of direct acting engines, coupled on to the cranked axle

of the hind wheels. These carriages were at first employed as drags, the passengers being drawn in a separate vehicle, but ultimately the passengers and machinery were carried on the same frame. The arrangement of framing adopted by Mr. Gurney and most others who carried out the principle of direct action is shown in Fig. 5. There is an upper and an under framing;

FIG. 5.



the engines are attached to the under framing, the passengers, boiler, &c., being carried by the upper one; the object of this was to keep the body of the carriage well suspended, the engines at the same time always maintaining their proper position relatively to the axle. Sir C. Dance ran these carriages regularly for four months, four times a day, from Cheltenham to Gloucester, during which time they carried about 3,000 persons, and travelled 3,500 miles; the distance, which was nine miles, was performed on an average in 55 minutes. After these carriages had been on the road a short time, the opposition began to grow stronger and stronger, and among the various means resorted to was a heap of stones about 18in. deep, laid across the road purposely, to impede the progress of the engine, which caused on one occasion the breakage of the driving axle. Bills were hastily passed through Parliament, placing prohibitory tolls upon them, in some cases amounting to £2; this line was then given up, and we hear little or nothing more of the efforts of Mr. Gurney.

The author then noticed the carriage of Mr. Walter Hancock, of Stratford, who commenced his career in 1827. This gentleman was unquestionably far more successful than any of his competitors, for his carriages were very superior, both in mechanical arrangement and workmanship, to any others that were then constructed, and considering the elementary state of engineering at the time, it is only surprising that so much success was attained. The boiler

consisted of a series of flat parallel chambers to hold the water, and placed side by side at a sufficient distance apart for the flame and heated air to pass up between them. Each of these flat vessels extends across the furnace; they were all connected at the bottom for keeping the water at a uniform level, which was generally from one-half to two-thirds full, and at the top of each was a steam pipe, which led into a larger one common to them all, by which the engines were supplied. To keep these water chambers at the required distance apart, and confer at the same time adequate strength, a series of vertical bars were placed between each pair; these bars were sometimes in a zigzag form in order that the flame should have to traverse a greater distance before finding an exit up the chimney. The lateral strain on the boilers was overcome by a system of very massive bolts, which pass through the plates in one entire length from outside to outside.

An increased efficiency was afterwards obtained by embossing these plates by pressing them hot between dies, which caused a series of hemispherical bosses to be projected all over their external surfaces, so that, when the chambers were brought together, the tops of these came in contact, and thus a series of spaces was formed between them, through which the heated gases ascended in a devious course, impinging successively upon each boss. By means of embossing them in this manner, the lateral strain was taken equally well without the necessity of using solid bars, which increased the weight and reduced the heating surface. The chambers were generally made about 2 in. wide, with a space of 2 in. between each. The proportionate size of his boiler, as compared with the engines, and weight of carriage, would be seen from the following example:—One of his carriages, called the Infant, having two cylinders 9 in. bore, and 1ft. stroke, had a boiler with 6 square feet of fire-grate, and 100 square feet of upright heating surface; the plates were made of good iron ⅛ in. thick. With this the average workiug pressure was 100 lb. per square inch, and on some occasions had been worked at more. The weight of the carriage when fully loaded could not be estimated at less than six tons. It would be seen that this boiler was designed on first-rate principles, and would compare favourably with any of our tubular boilers of the present day; in fact, it may be questioned whether, owing to their extreme safety, lightness, and facility of repair, they were not more adapted for the smaller class of steam carriages than any that are now being used. One advantage that attended them was, as no

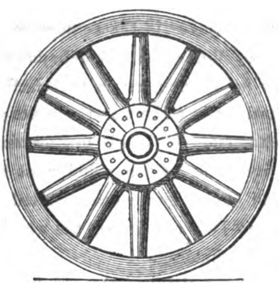
danger could arise from the explosion of any one chamber, the working strain on the plates might be brought much nearer their ultimate strength, and consequent lightness obtained. A fan was used to urge the fire, the ash pan being completely cased round, except where the mouth of the fan was attached. This kind of boiler just described was the one that he used throughout all his carriages, with merely a few trifling alterations from time to time. With regard to the arrangement of the engines, &c., he tried several plans. The first carriage he constructed was to carry four persons; it had three wheels, and was propelled by a pair of oscillating cylinders, coupled direct on to the one front wheel. The object of driving on to one wheel was evidently to facilitate turning curves. This plan was not deemed suitable for carriages of large size, but it was sufficiently successful, however, for a steam carriage company to be started, with Mr. Hancock at their head. The following is a description of the class of carriages constructed for this company:—In order to avoid cranking, the main driving axle, which was found in other carriages to be continually breaking, and also to allow conveniently for the play of the springs, an endless chain was adopted in preference to direct action, a vibrating link being placed between the engine shaft and the axle to take the strain caused by the transmission of power, and to preserve a uniform distance between the two.

The driving wheels were outside the framing, and ran loose on the axle, either or both being connected by clutches. These clutches were on the outside, and were furnished with levers for the stoker to throw them in and out of gear when turning curves. A little play was left between the stops on the clutches, so that a winding road might not oblige either wheel to be disengaged. The fan was driven by a strap from the engine shaft. In all Hancock's carriages the passengers were carried on the same frame as the engines. The largest one he constructed, called the Automaton, was capable of conveying twenty-two persons.

The whole of the engines, crank shaft, pumps, and all the other parts, were supported on springs. The cylinder was arranged to work downwards, and the driving axle and crank shaft were geared to make an equal number of revolutions. The steering was effected by means of a chain passing round a small drum and connected to the wheel plate. Under ordinary circumstances only one driving wheel was thrown in gear, but, on slippery roads or steep hills, they were both clutched to increase the adhesion. Hancock

constructed in all nine steam carriages, some of which ran on the public roads for several months together from Paddington, Islington, and Stratford to the Bank; but, owing to the general dislike that prevailed at the time, they did not meet with the patronage that was expected. Before leaving these carriages we must notice the kind of driving wheel adopted, the design of which was no doubt novel at the time, and is a beautiful combination of strength and lightness. Fig. 7 represents one. The spokes towards the

FIG. 7.



centre are wedge-shaped, and abut against each other, their lateral strength being provided for by wrought iron discs on each side: these, by being bolted through, confined the spokes very securely in their places. By this arrangement as much strength in the spokes at the centre was obtained as possible. The author then described the carriage of Messrs. Summers and Ogle, patented in 1830. The principal feature of this was the adoption of an annular tubulous boiler, somewhat similar to those used in the American steam fire engines. There were three cylinders acting direct on the driving axle. The experiments tried with this were far from successful.

In 1833, Colonel Maceroni constructed a steam carriage similar to Gurney's, with the exception of the boiler, which was a decided improvement upon its predecessor. It was an upright water tube one, the outside and fire-bars all consisting of tubes. It had two cylinders, 7½in. bore and 16in. stroke. It has been said to have run 1,700 miles without requiring repairs; but this, of course, must be doubted.

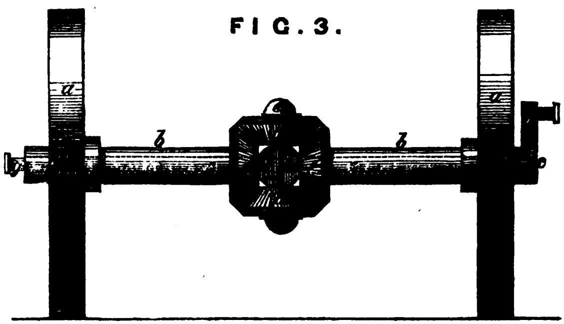
The last experimentalist of the earlier days of common road locomotion noticed was Mr. F. Hills, of Deptford. This gentleman devoted much time

and expense to the subject, and having been very successful with his experiments, a company was set on foot for working his patents. Among the numerous performances of his carriage may be mentioned that a journey from London to Hastings and back—a distance of 128 miles—was performed in one day, it being accomplished in half the time occupied by the stage coaches.

The principal improvement introduced by Mr. Hills, from its extreme ingenuity, and the perfect manner in which it attained the object in view, calls for particular attention. One of the great difficulties attending the designing of locomotive carriages is the connection of the driving wheels with the engines, so as to obtain the full adhesion of both wheels, and at the same time to allow for turning curves with facility. Mr. James fixed each of the driving wheels upon a short and separate shaft, and applied two cylinders to drive each. Hancock in his first carriage used three wheels, and propelled by the front one. Gurney and most others had clutches to throw the wheels in and out of gear when required; but as it was impossible for the steersman to lock and unlock the wheels at every turn, great friction was created by the skidding.

By Mr. Hills' arrangement the adhesion of both wheels is constantly exerted to propel the carriage, without the slightest attention on the part of the driver. Fig. 3 is a sketch of this plan:—*a*, *a*, are the driving wheels fixed on two tubes, *b*, *b*, through which the axle or driving shaft, *c*, passes; *d*, *d*, are two bevel wheels having the pins *e*, *e*, for their centres, these pins are forged in one with the shaft that goes through. The wheels

FIG. 3.



d, d, gear with the two bevel wheels *f, f*, fixed on the tubes *b, b*; *g, g*, are the cranks to which the connecting rods are attached. Upon examining the figure it will be seen that so long as the wheels continue to run in a straight line the tubes *b, b*, do not revolve upon the axle, but turn with it and carry round the wheels as if fixed to the axle; but upon any deviation from the straight, the wheels turn at different speeds more or less according to the sharpness of the curve, and then the tubes *b, b*, revolve at a slightly different speed from the axle, and the bevel wheels are brought into action, which, although slowly in motion, continue to exert the same pressure as before. A mode of driving somewhat similar to this has been introduced by Taylor, of Birkenhead, in his traction engine, and there is no reason why it should not be generally adopted.

About this time the opposition to the introduction of steam carriages became so excessive that wherever one was run a bill was immediately passed through Parliament laying a prohibitory toll upon it; and owing to this, and also that the attention of capitalists was being drawn towards the construction of railways which were then about to be generally introduced, those few experimentalists who had proved themselves to be successful were forced to abandon it and turn their attention to something remunerative But although little or nothing has been done from that period until recently, the engineer of the present day is very differently situated to what he was then. He has now a variety of designs for boilers which have proved themselves efficient. He has link motion for reversing, and various other details which tend to reduce the difficulties of his task and render success more certain.

Mr. Rickett, of Stoney Stratford, appears to be the most enterprising and successful engineer who has taken up this particular subject.

The first carriage constructed by this gentleman was finished in the year 1859. It was carried on three wheels—two driving ones behind, and a single steering one in front. The main framing of the carriage was formed by a pair of longitudinal iron tanks. The boiler was fixed at the back, above the coal bunker, and the steam cylinders were placed horizontally, one on each side of it, an ample seat for three being provided in front, between the forward end of the boiler and the steering wheel. The crank shaft was beneath the seat, the piston rods being coupled on in the usual manner.

On one side of this shaft was a small pitch wheel, over which passed an

endless chain, which also passed over a larger chain wheel upon the driving axle.

The relative sizes of these two wheels were as 1 to 2½. The driving axle was placed as nearly under the boiler as possible, and worked in axle-box guides, in the usual manner, a single spring being used to support the framing.

Behind the boiler was a foot-board and a seat for the stoker. One driving wheel was keyed firmly on the shaft, the other running loose, except when thrown into gear by a clutch. The engine was steered very readily by means of a lever connected with the fork of the front wheel, which latter passed through a guide in order to allow for the up and down motion of the spring. The driver, besides having the steering under his control, was provided with the reversing lever and break handle. which gave him all necessary command over the carriage.

The cylinders were 3in. diameter and 9in. stroke, the maximum pressure 100lb. The driving wheels were 3ft. in diameter. The boiler was short, in order that the variations in level should not affect it, and was on the internal flue and return principle. It was made of steel, and was 19in. in diameter, and afforded an area of 31 square feet of heating surface. The water tanks, as before said, acted also for the framing, and contained sufficient for eight or ten miles run. The amount of fuel carried would last for twenty to twenty-five miles. The weight of the carriage itself was about one ton, and when fully loaded it weighed about one and a half tons.

On good level roads this carriage ran upwards of twelve miles an hour, and, considering that it was the first made of this class, may be looked upon as very successful.

In the following year, viz., 1860, Mr. Rickett brought out another. This was made a size larger than the last; it had 3½in. cylinders, and the maximum pressure used was 150lb. This engine was found to travel exceedingly well, and on good roads attained high rates of speed. The main framing of this, as in the former one, constituted the tank, and the general arrangement of the parts was similar, with the exception that the pitch chain to transmit the power from the engine shaft to the driving axle was done away with, spur-gearing being substituted. The bearings of the driving axle carried the springs, and worked in guides set at a considerable angle from the perpendicular, but at right angles to a line drawn connecting the centres of the two axles, so that the motion of the springs did not

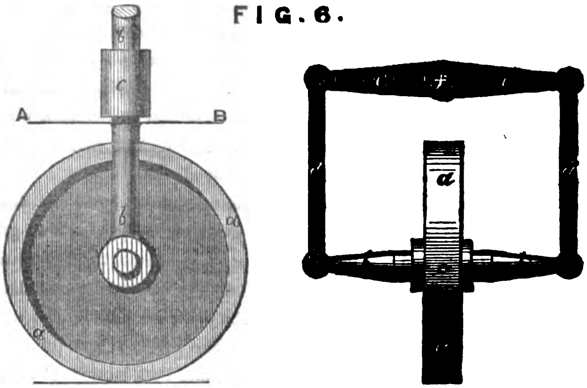
materially affect the gearing. There were two sets of spur wheels and pinions giving proportionate speeds of ten and four miles an hour, so that in ascending hills or running on a rough piece of road, by throwing the slower speed into gear, the actual tractive force was multiplied two and a half times. The carriage was intended to carry three persons, who sat facing the motion on a seat in front. Its weight when empty was one and a half tons, and when fully loaded about two and a half tons. This carriage was similar to that made for the Earl of Caithness, whose doings in Scotland we have from time to time heard so much about. Mr. Rickett had constructed several of them, some of which have been sent abroad.

The author then passed on to describe one constructed by Messrs. Garrett and Marshall for George Salt, Esq. It was exhibited last year at the Agricultural Show at Leeds, and was now in the eastern annexe of the International Exhibition. The following are a few of the general particulars:—The boiler is of the best Lowmoor iron; the joints are flanged and welded, suitable for a working pressure of 150lb. The fire-box and tubes are of copper, which are turned to fit the tube plate, and then hammered over and brazed in. There are three wheels—the two driving ones are of steel, with cast iron bosses, and an inside and outside tyre, with hard wood between; they are 4ft. diameter and 6in. wide. Either wheel can be disengaged by withdrawing its corresponding clutch, which is on the outside. The front and steering wheel is 3ft. diameter and 6in. wide. There is one point connected with this wheel worthy of special attention, viz., that besides being held in its place by a vertical forked spindle, which passes through guides; it has a parallel motion which transmits any strains taken by the wheel, and given out at its axle to a fixed pin or fulcrum on the frame. Thus the brunt of obstacles on the road is taken quite independently, and the steering is left free from any injurious strain.

Fig. 6, shows the usual method of connecting the front wheel. *a*, is the wheel; *b*, *b*, a forked spindle passing through the guide *c*, which is firmly attached to the frames, on the top are the springs, and also the guiding handle. It is evident that any obstruction to the forward motion of the carriage will have a tendency to break the spindle at A, B. On the right hand is a plan of the arrangement referred to. *a*, is the wheel; *b*, *b*, the shaft on which it revolves; attached to the eyes, *c*, *c*, are the links; *d*, *d*, the other ends, of which are connected to the lever *e*, which moves on

he pin *f*, which is firmly fixed to the framing. It will be seen that the wheel *a* can be turned either to the right or to the left about *o* as a centre, quite unaffected by the links *d*, *d*, and the lever *e*, which maintain the dis-

FIG. 6.



tance from *f* to *o*, under all circumstances the same, and thus the upright spindle is relieved from the injurious strain, which we have seen in the former case had a tendency to break it at A, B.

The action of this is represented by Fig. 6. The cylinders are 6in. bore and 8in. stroke. They are connected to the driving axle by spur gear, which is in duplicate on either side of the engine in the proportion of five to one. The cylinders are fitted with slide and expansion valves, and arranged when required to cut off as early as one-seventh of the stroke; this expansive motion of necessity deadens the noise of the blast to a minimum as well as economising steam. The boiler is fed by a small donkey, as well as a fixed pump. The tank carries water for ten to twelve miles, and the fuel space will contain coal enough for about twenty miles. This carriage is furnished with seats, including the steerer and stoker, for nine persons. Its total weight, when fully loaded, is from four and a-half to five tons, about four-fifths of which is carried by the two driving wheels and one-fifth on the steering one.

It will be noticed that the proportionate speed of the engines is very great; indeed, so much so that if the carriage were made fast, there would be purchase enough to make the wheels skid. The author then gave a brief

description of Yarrow and Hilditch's Steam Carriage exhibited in the eastern annexe of the late International Exhibition, with which he had been connected, manufactured by Mr. T. W. Cowan, of Greenwich.

It is made to carry thirteen persons, including a steerer and a stoker. The steerer sits in the centre of the front seat, having one passenger on each side. Back to back with them are seats for three others, and for six more (three on each side), facing each other. By this mode of arranging the seats, it can conveniently be covered in, with a door on one or each side for entrance. The stoker is placed in the tender behind. The boiler is of the ordinary upright tubular type, the outside shell being steel. It is 2 ft. diameter and 3 ft. 9 in. high; it has 40 square feet of heating surface, and a fire-grate 21 in diameter. It is fitted with a perforated steam pipe round the top to reduce the chance of priming. The main framing of the carriage is ash, 4½ in. deep, lined with edge plates ¼ in. thick. To the outsides are bolted two iron foundation plates for carrying the cylinders, &c. On the inside of the framing are the driving wheels, which are 3 ft. diameter; they have a cast iron boss similar to Crosskill's, and are both keyed on the main driving axle, on the outside of these wheels come the bearings which carry the springs, beyond these are fixed the cranks, to which one end of the connecting rod is attached, the advantages claimed for thus arranging the parts are, "that the guage of the hind wheels being considerably reduced, does not necessitate throwing the inner one out of gear when turning curves; and, secondly, that direct action is obtained without having the axle cranked, which past experience has shown to be highly objectionable, as the continuous jolting very soon breaks it."

In order to keep the axle in its right position, a link is employed in preference to axle-box guides, as, by its use, far less friction is caused, and the distance between the shaft and cylinder is maintained precisely the same, and the action of the valves remains unaffected by the vertical play of the springs. One end of the link is connected to the axle bearings and the other to a provision on the foundation plate. The working parts are entirely boxed in to protect them from dust and grit. The cylinders are 5 in. in diameter and 9 in. stroke.

When fully loaded the weight is 2½ tons; about 40 cwt. is carried on the hind wheels, and 10 cwt. on the front ones. All the parts of the engines

are made as light as possible, steel and malleable cast iron being introduced wherever practicable.

The steering is effected by means of a chain. The steerer is also provided with a reversing lever, so that the carriage is entirely under his control. The tank is placed under the seats, and the coal in the tender behind.

Fig. 1, represents a design for a large steam-carriage capable of carrying from thirty-four to thirty-six persons. The boiler, tank, and fuel are placed in a compartment at the back. The engines are bolted to the side frames, acting direct on 4 ft. driving wheels. They are enclosed by the outside casing, as shown, which can be easily removed when required.

Direct action is unquestionably preferable to gearing in a case such as this, as the engines do not take away from the room of the carriage; they are easily got at; and, as the motion of the working parts is slow, the wear and tear is lessened. The exhaust is sent out at the back at an angle, and, if thought fit, the funnel can be made to project. The mode of entrance is by steps on each side in front—the inside passengers passing in at a door, the outside ascending the ladder. The driver stands on the platform in front, and is provided with suitable steering apparatus, and also the reversing lever. The stoker is placed behind. The front wheels are 3 ft. 6 in., and the driving wheels 4 ft. in diameter, the length of the body of the carriage is 16 ft., and over all 21 ft.

The author having described those steam carriages most worthy of notice which had been constructed from time to time, and pointed out the particular features of each, proceeded to consider the following general principles, which, whatever be the mechanical arrangement of the parts, remained the same.

1st.—To determine the necessary tractive force.

2ndly.—The necessary requirements in good driving wheels.

3rdly.—The size and best description of boiler.

4thly.—The working expenses as compared with our present vehicles.

First. To determine the necessary tractive force. The chief resistance to the forward motion of a vehicle at common speeds, and on ordinary roads, is that which arises from the roughness and softness of the surface—the one causing loss of power by its being expended in producing shocks and jolts, and the other due to the sinking in and consequent friction that arises.

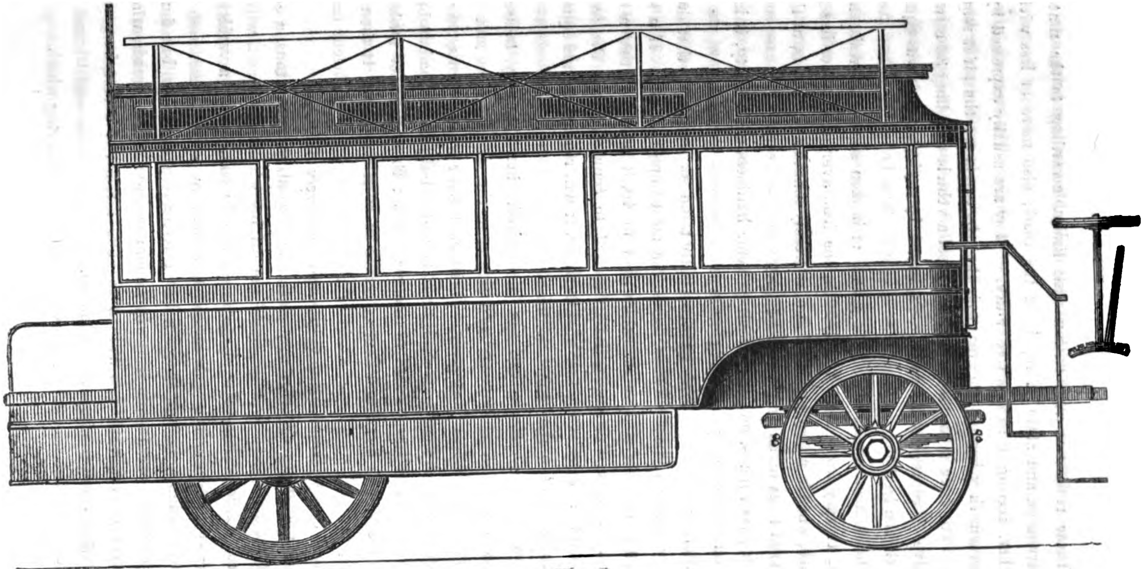


Fig. 1.

These resistances vary within wide limits, according to the material, construction, and state of repair of the road; also more or less with the weather, according as it is wet or dry. They are usually expressed by the proportion they bear to the gross weight of the carriage; thus, if it required a constant force equal to 1 cwt. to propel a vehicle weighing 30 cwt., the tractive force required would be expressed by saying that it was equal to 1-30th the load.

On common roads, made with gravel or broken stones, the resistance is found to vary from 1-40th to 1-20th, the load averaging rather less than 1-30th, when in a very bad condition, or freshly macadamised, it is, at times, increased to as much as 1-10th the load.

On paved roads, owing to their extreme hardness and solidity, it is less than on others, rarely exceeding 1-70th.

Another resistance which has frequently to be encountered is that due to gravity, and, on steep inclines, forms the most important one. If a slope ascends at the rate of 1 perpendicular foot in 40, it is evident that a force equal to 1-40th, the load will be required to counterbalance the ascent alone, and if it be at the rate of 1 ft. in 30, it will require a force equal to 1-30th the load, and so on.

Now suppose a steam carriage is required, when necessary, to ascend inclines of 1 in 10, which may be considered as the steepest to be met with on the main roads in this country. This ascent alone will require a tractive force of 1-10th the load. To this must be added 1-10th, the load as being the maximum resistance due to the road itself; these together make $\frac{1}{5}$, adding to this 1-20th, to allow a margin of surplus power. It then becomes $\frac{1}{4}$ the load, which may fairly be considered as amply sufficient under the worst circumstances, more only causing useless weight.

Now presuming the carriage, when fully loaded, to be five tons, a constant force acting at the periphery of the driving wheels of 25 cwt. will be required. This, it has been already seen, can be obtained by a variety of means—cog wheels, endless chains, direct action, &c.

Under ordinary circumstances a less tractive force than $\frac{1}{4}$ will be found amply sufficient, and in countries where there are good military roads, which are tolerably level, a still less will suffice; but it must, of course, be varied according to the requirements of the case.

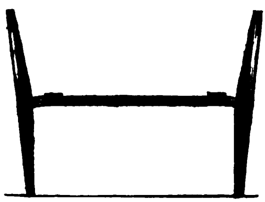
Secondly. The necessary requirements of a good driving wheel.

In the construction both of steam carriage and traction engines, the designing of a good, strong, and suitable driving wheel has been found to be one of the most serious mechanical difficulties.

Garrett and Marshall's steam carriage, when shewn at Leeds last year, had driving wheels which consisted merely of a skeleton frame of steel with a tyre shrunk on. Since then wooden fellies have been introduced between the tyre and spokes. This addition has no doubt been found necessary to deaden the shocks, which would otherwise be severely felt, and very soon destroy the wheel.

In Bray's traction engine layers of wood and india-rubber have been secured on the inside of the tyre to secure the same effect, and it has been found, as a general rule, that in an iron wheel an elastic medium for the tyre to bear upon is absolutely necessary. The result produced by not taking this precaution is that, owing to the continual blows upon the tyre caused by the obstacles in the road, it gradually expands, and eventually works loose and comes off. This difficulty is experienced with wooden wheels, although to a less extent, and is, in ordinary practice, most efficiently and ingeniously overcome by what is termed dishing. The spokes are inserted into the box at an angle, and when running the wheel assumes the position as shown in Fig. 2. After the spokes are driven well in and

FIG. 2.



the fellies fitted, the tyre is shrunk on. This shrinking on by contracting its diameter produces an increased dish, the consequence of which is that the spokes always have a tendency to spring back to their original position, and as the tyre becomes larger by wear the spokes and fellies follow it up, the wheel remaining equally good, and to all appearance the same as it was at first. There are other reasons for dishing wheels, but this just mentioned is by far the most important.

Upright wooden wheels, as might be expected, last a comparatively short time, the tyre continually working loose and requiring shrinking on afresh.

In steam carriages, as the axle revolves and the wheels are fixed to it, dished ones are unfortunately not applicable. The author considered when not more than 4ft. to 4ft. 6in. in diameter, a wooden wheel was preferable to an iron one; such for instance as that adopted by Hancock, which is of a particularly strong form, especially for transmitting a twisting strain.

There is one point connected with this portion of the subject which it is as well to notice, as there still remains a doubt with many persons respecting it, viz., the amount of adhesion that the wheel has on the road. This is a matter of considerable difficulty with traction engines, where the load is drawn; not so, however, with steam carriages, where it is carried. It has frequently been proved to be so beyond a doubt. Mr. Gurney, among a variety of experiments, found that under the worst circumstances that ordinarily occur, the adhesion of a plain wheel on the surface of the road without skidding perceptibly was sufficient to propel a gross load of from 2 to 2½ times that which it carried itself.

Thirdly. The best and most suitable form of boiler for steam carriages is a matter upon which, as might be expected, there exists great difference of opinion, and will, no doubt, remain unsettled until many experiments have been tried and more experience obtained.

The boiler preferred by Mr. Rickett is cylindrical, with an internal flue and return tubes. The fire-grate is placed in the front portion of the flue, from which the flame passes to the other end, and then returns round a smoke-box through a number of small tubes placed on each side.

This description of boiler has been attended with considerable success, owing to its shortness it takes up comparatively little room and is not perceptibly affected by inclines.

It is needless to say anything in favour of the ordinary fire-box boilers; their general adoption and universal success in locomotive practice unquestionably prove their suitability for steam carriages.

The ordinary upright tubular boiler is one which has been much resorted to. It particularly fulfils the requirements of the case. Being vertical, and not horizontal, it occupies but little space. It is quite unaffected by inclines, and is lighter than any other, inasmuch as when the end of the

journey is approached the water level can be let down to within a few inches of the top of the fire-box without danger, and consequently less tank room need be provided. It also has the advantage of superheating the steam, to a very great extent rendering the exhaust generally invisible—a very important point. The chief objection urged against their use is that they are apt to prime. This, however, can greatly be reduced, if not entirely prevented, by keeping the boiler short, in proportion to its diameter, in order to obtain more area at the water level, and also by working the water moderately low, to allow plenty of steam space. A perforated pipe placed close to the top, to draw the supply from, will also be found of service. In determining the size of boiler for any particular case it must be remembered that in fixing the dimensions of the engines it is necessary to have sufficient tractive power to overcome the maximum resistance which was taken at $\frac{1}{4}$ the load. In reckoning the amount of evaporative power in the boiler, the average resistance has only to be taken into account. This has already been estimated at 1–30th the load; therefore a constant mechanical effect is required equal to 1–30th the load raised through a space corresponding to the speed of the carriage. Having this it can be ascertained for any case the horse power to which this effect will be equal; for example, taking the total weight of a carriage when fully loaded to be five tons, and required to travel at an average speed of ten miles an hour, then the mechanical effect required in one hour will be $3\frac{1}{3}$ cwt. raised through a space of ten miles. This will be found to be equivalent to the development of 10-horse power.

As in small boilers the combustion is not so intense as in larger ones, and as lightness is of greater importance compared to economy than under ordinary circumstances, the proportion that the firegrate surface bears to the heating surface ought to be much greater than usual in locomotive practice, say, not less than 1 to 25, *i.e.*, 1 square foot of fire-grate surface to 25 of heating surface; then taking 8 square feet of heating surface as equivalent to one actual horse power, which in most cases would be found sufficient; a 10-horse boiler would require 80 square feet of heating surface, and not less than $3\frac{1}{5}$ of fire-grate.*

* In cases where the average resistance is greater than one-thirtieth, or the roads very hilly, or the fuel of inferior quality, the above proportions must necessarily be increased.

With regard to the mode of feeding the boiler, a pump and an Injector would no doubt be found to answer well, the one to work when the carriage is in motion, the other when at rest.

An Injector does not act satisfactorily while travelling, for it requires great attention, as the jolting and constant fluctuations in pressure affect it.

Fourthly. The cost of working steam carriages as compared with other vehicles. The various expenses attendant upon each vary within such wide limits according to the circumstances under which they are placed, as to render it impossible to draw a comparison between them which will hold good in all cases. The following example will, however, serve as a tolerably fair guide; the cost of running a two-horse omnibus in London from sixty to seventy miles a day averages about £17 per week; each omnibus requires eleven horses to work it; the keep and loss in horse flesh alone amounts to no less than £9; the rest is due to the coachman, conductor horsekeeper, duty and cost of repairing, and depreciation of omnibus. The original outlay may be reckoned at about £450, a good omnibus costing £120. This is capable of carrying twenty-six persons, twelve inside and fourteen out. A steam carriage suitable for the same number of persons to travel at the same speed, say, eight miles an hour, would require from 9 to 10-horses power, and would weigh when fully loaded from 5½ to 6 tons, and cost about £450. The cost of working may be estimated as follows (taking the consumption of coal at the rate of 10lb. per horse power per hour):—

2½ tons per week	£2	10s.
The steeerer and stoker	3	10
Depreciation and repairs at 50 per cent. per ann...	4	7
Duty, we will presume to be the same as an omnibus.	1	15
Minor expenses, including water, oil, tolls, &c. ..	1	0
	£13	2

The difference between the two in favour of steam is about £4, and can be traced chiefly to the cost of keep of horses; it must be further borne in mind that, when not working, they still cost a large sum, while the steam carriage consumes nothing.

Connected with the relative economy of steam and horse power, one general principle may be noticed, viz., that owing to the comparative small mechanical effect produced by horses travelling at high speeds, the economy arising from the adoption of steam is more marked as the speed increases.

Before coming to a close there is one point connected with the introduction of steam carriages on common roads deserving particular attention, viz., the effect produced with reference to the frightening of horses, and the best means of reducing, and, if possible, entirely avoiding it.

It is not a matter to be wondered at that the traction engines which have, until very recently, frequented the streets of London, have caused great alarm in this respect. Considering the size, strangeness, and ugliness of their appearance, and the noise and puffing produced by the blast, it would have been remarkable if such an effect had not been produced; and it would, no doubt, take a long time before their general adoption would have been unattended with dangerous results.

The case, however, assumes a very different aspect with regard to steam carriages. They could be constructed in external appearance very similar to many vehicles now running with passengers inside and out, the boiler and working parts entirely enclosed, and, consequently, quite out of sight.

There cannot be a question but that a carriage similar to this would have far less tendency to frighten horses than the traction engines. The only difficulty of any importance is to properly dispose of the steam. Mr. Rickett has proposed to condense it. About eighteen months since he made an experimental steam carriage worked at 250lb. per square inch very expansively, and condensed it with 800 square feet of surface exposed to currents of air. This, however, was not found to produce the desired effect. The expense, difficulty in obtaining sufficient surface, weight, the necessary mechanism to produce a blast, all tend to prevent this system from being adopted.

It has also been suggested to let the steam issue out at the back of the carriage in as continuous a stream as possible.

As it would materially injure the draught if the steam were not to enter the funnel in puffs, the only means of effecting it to any extent would be, if possible, to equalise it after having passed out of the funnel, and before issuing into the open air.

It might be effected to a certain extent by letting it pass into some spare space which would act as a kind of air vessel. If then allowed to find exit behind the carriage it would be almost out of the sight of the horses approaching, and only seen by those following it, which would not prove a very serious objection. The exhaust steam ought to be reduced in

quantity as much as possible by carrying out the principle of high pressure and expansion.

There is another cause to the frightening of horses which, unfortunately, does not seem capable of a remedy. It is due to the strangeness in appearance of a vehicle running along without any evident source of propulsion. It is impossible to say to what extent this affects the matter, and probably it would not take long before the horses would get accustomed to it. In the case of traction engines, it might be greatly removed—presuming them properly boxed in to hide the boiler and machinery if a horse were placed in front in some shafts, it would assist in steering, and, at the same time, take off that novelty of appearance just referred to. This principle is exemplified in many self-propelling portable engines, and there is no doubt that it has a marked effect in this respect.

With regard to the management and control of steam carriages, no danger can be feared from any difficulty on this score, as, with suitable steering gear, and not much weight on the leading wheels, the direction is under the perfect command of the driver. Take Aveling's engine, for example. In a like manner, with effective brake power, and, in cases of necessity, by reversing the engines, the carriage can be brought to a standstill much sooner than with animal power.

The author then brought his paper to a close, and said that he trusted he had been able to show that there were no insurmountable difficulties to the introduction of steam carriages, and that in many cases they would be attended with beneficial results.

DISCUSSION.

Mr. H. P. Stephenson thought steam carriages might be applied to what he would term agricultural railways; and he strongly believed that future progress would be either by the construction of much cheaper lines of railway than had hitherto been made, or by the creation of tramways along the roads in country districts on which these steam carriages might be introduced. Difficulties in the way of constructing cheap railways existed in the obstruction offered by landowners and in the requirements of the Government Inspector; he thought, therefore, they might be driven to the construction of tramways along the lines of traffic, and the traversing

these lines by steam carriages. He should like to know what performances had been made by Yarrow and Hilditch's Steam Carriage, and whether these performances had been continuous. His strong impression was, that the great wear and tear of these carriages, running over rugged and steep inclines upon common roads, would be such that they would not be found of much practical use without great improvement, or the introduction of rails for them to run upon.

Mr. F. C. Reynolds said, that Mr. Stephenson had suggested that it might be advisable to have something equivalent to railways or tramways; but he thought it would be manifest to every one that when they had made tramways in almost every possible place, and railways were as thick as they well could be, nevertheless there must be a great many roads and streets, where, if it were possible to obtain steam carriages fit to run on ordinary highways, they would be most desirable. Mr. Yarrow had shewn—or had stated—that steam carriages might be worked at considerably less cost than common omnibuses (taking the depreciation at 50 per cent., which was probably a high figure), and that a saving, as compared with the omnibus, of £4 per week might be effected. Even supposing that the depreciation were to be considerably more than that given—that the cost of working the steam carriage were to be as great as that of the common omnibus, he thought it would hardly be denied that the steam carriage might offer far greater convenience for travelling, and that it might run with quite as great a speed as the London omnibuses did. With respect to horses being frightened, about which so much had been heard of late, he thought it was because the steam carriages were new things, and that they were followed by a crowd of people who kept up a continual turmoil, and this was really the cause of alarm; but when people got more used to them there would be no danger in this respect. There seemed to be some difficulty as to the wheels, especially the driving wheel. There were objections to make them "dished;" and he did not believe a real efficient wheel, satisfactory in all points, had yet been made. He had heard that there were imperfections in Hancock's wheels—that when used the tyre had become loose; therefore, he considered that any suggestions with regard to the driving wheels of these carriages would be most valuable. The arrangement shewn in Fig. 5, with regard to the cylinders and the crank shaft, shewed considerable ingenuity, and he believed would be found to answer

well. The carriage itself was supported well on the springs and wheels, whilst the cylinders were on an elastic medium. Whether the play of the spring would be sufficient or not he was not prepared to say, but he hardly thought it would. He did not think the difficulties of the high road would be as formidable as might at first be supposed; and as to the steerage, he thought that a matter of little inconvenience, as previous experience had demonstrated.

Mr. Edward Reynolds remarked, that the description given of Hancock's boiler was not strictly correct. The flat chambers were connected by two bolts passing through the whole of the chambers, one through the steam spaces, and the other through the water spaces. Perforated ferrules were used to prevent the sides of the chambers from yielding to the strain on the bolts which was necessary for making the joints. The external strong plates were heavily stayed and connected by bolts passing the ends of the chambers. He wished to call attention to the fallacy of supposing that this was a light construction of boiler. The heating surface would weigh as much as it would in the form of tubes of the same thickness, whilst a cylindrical shell must obviously be lighter than the flat ends with their stays and connecting bolts. This form of boiler was very liable to priming, which was obviated by the use of very small steam pipes. He considered that the plain vertical boiler used by Mr. Yarrow was much inferior to the ordinary locomotive boiler, not only in the smaller efficiency of the same amount of heating surface, but mechanically in the extreme difficulty of keeping the tubes tight, owing partly to the great expansion and contraction due to the overheating of the part passing through the steam. He had had costly experience of the defects of this class of boiler, and he found by correspondence with the leading locomotive engine-builders in America, that they had also been obliged to abandon their use. An incidental defect of this boiler is, that the top-heaviness renders it inconvenient to use a sufficiently large smoke-box, which is a matter of much importance when the draught is produced by the intermittent action of the blast. In an experiment made on a locomotive in 1847, by reducing the internal capacity of the smoke-box to a mere passage from the tubes to the chimney, the consumption of fuel was largely increased, whilst the steam-producing power was seriously diminished. Another point of practical importance is the construction of the driving wheels. Hancock's wheel, though sound in

construction, was too rigid. He had known wheels of this class made dished, the axle remaining horizontal with good results. Another method would be to dish the spokes in the place of the wheel, placing them in the nave in pairs, parallel to each other, or nearly so, and springing their extremities to the usual distance apart in the felloes. With respect to Messrs. Yarrow and Hilditch's carriage, it was still far from perfect; but the designers had shewn a thorough appreciation of the difficulties to be overcome, and the general construction was sound in its character. As to depreciation, he did not see why so large an amount as 50 per cent. should be anticipated; there was no reason why at the slow speed at which it is possible to work such a carriage the machinery should not last as long as that of agricultural engines, in which the depreciation was shewn by experience to be very moderate.

Mr. Olrick said, that he had seen a boiler in which the tubes hung down over the fire; it was designed by one of the members of the Society (Mr. Field). In this boiler the circulation of the water was effected in the most beautiful manner. It was his opinion as regarded the wheels, that a light iron wheel might be made which would answer every purpose. In the "Engineer" of 3rd October, 1862, there was an illustration of Adams's wheel, not with steel, but india rubber springs; and he thought a light iron wheel might, with these springs, be made to answer the purpose better than a heavy wooden wheel. Mr. Yarrow remarked, that the engine of Ricketts was only of a slow motion, but a light engine and slow motion would not do together. They must either have slow motion and a strong heavy engine, or quick motion and a light engine. There was no occasion to be afraid of making these engines go too quick, because he had seen marine engines of 600 or 800-horse power moving at about sixty revolutions per minute. He should like to know whether Ricketts boiler smoked or not? because he considered it was almost impossible to get a perfect combustion in so short a boiler. In respect to the proportion of grate and heating surface, he wished to know why it was necessary to have such a small proportion? In locomotives it was 1 to 60, but Mr. Yarrow gave 1 to 25. Regarding injectors, he thought that a great deal of prejudice existed against them. He thought they would be found to work exceedingly well with proper management. There were many instances where an injector had been working for three years without a single interruption. With respect to the horses being

frightened, he followed Bray's traction engine, before Sir Richard Mayne forbid its use, for 2½ miles, and during that time it passed a great number of horses, and not a single one got frightened by it. He hoped that the measure against traction engines would soon be abandoned. He considered chains superior to wheel gearing. It was also a great disadvantage to any locomotive or traction engine to have perpendicular cylinders.

Mr. Parsey thought that they had to determine first whether, if they had got steam carriages perfect, they had an application for them; the paper raised the whole question of railways, tramways or common roads, and he did not perceive any great improvement in the proposed carriage, and considered the weight too great to run on a common road, except it was in very good order, but if it was under repair, the carriage could not pass over it. The streets of London were unable to accommodate the traffic, and in the country the railways required feeders, and tramways or steam carriages were proposed to meet the cases. In London the tramways had been tried and taken up again; and it appeared to him that London street-traffic could only be worked by horses; but in the country, if the traffic required improved means of conveyance, that either tramways or railways must be employed to obtain any advantage.

Mr. F. Young had paid considerable attention to this subject for the last three years, and could see no difficulty in steering steam carriages. The Earl of Caithness had travelled from town to town at the rate of fifteen or sixteen miles an hour without any difficulty. He believed that where some of the railway companies had opened branch lines, steam carriages would have answered their purpose equally well, and at a far less cost. A branch line would cost at least £10,000 per mile, and steam carriages could be introduced at the cost of a single mile. Thus, if they took the interest on the capital and the whole of the working expenses, he considered it would be decidedly in favour of steam carriages. The question of the steam carriages frightening horses he thought was much exaggerated; he had superintended a road engine working in Manchester, and had not found the horses at all affected by it.

Mr. Yarrow, in reply, stated that the carriage referred to by Mr. Stephenson, was made about three weeks before it was sent to the Exhibition. On its first trial, before it was quite finished, it ran to Bromley, answering well, but in returning the injector got stopped up, and some of the

packing in the pipes got heated, which caused some delay, but they reached home safely; it was then completed and ran on another trial to Horsham, again answering well, although there were detentions on the road from the leakage of pipes, &c. In Hancock's boiler the water entered at the bottom and the steam escaped at the top, thus rendering the circulation perfect. He considered that steam carriages would answer well as feeders to railways, in Germany especially, where the roads were exceedingly good, and, where a large outlay at first was of considerable importance steam carriages would be very applicable; and if tramways were laid down these carriages could be used with very great advantage. With reference to the weight of a steam carriage, he might say that a three-horse omnibus weighed from 30 to 35 cwt. and carried forty passengers, making a total weight of not less than four tons, and these ran in the London streets without any difficulty. He thought that steam carriages would not be required to run at a high rate of speed.

The Chairman, in closing the discussion, said he thought steam carriages would be desirable in many places, where a large outlay could not be made, either to run on tramways or on the common roads, wherever the outlay would warrant it, a tramway would certainly be worked more economically.

November 3rd, 1862.

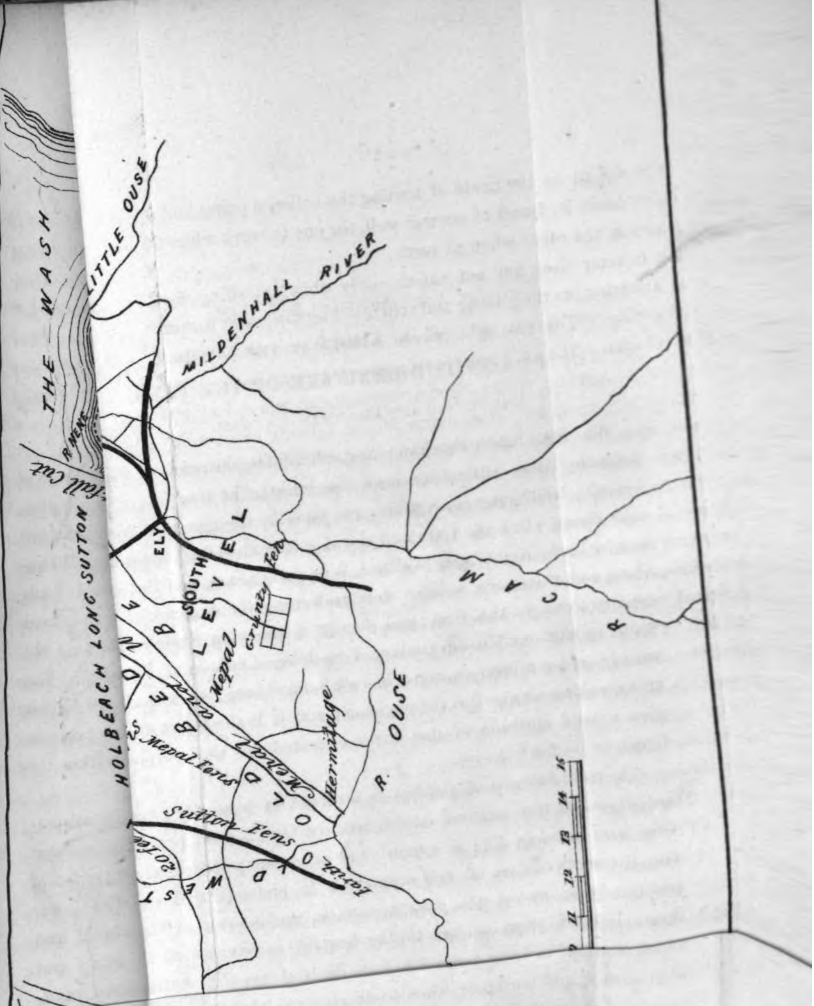
C. L. LIGHT IN THE CHAIR.

ON THE DRAINAGE OF THE FENS.

BY BALDWIN LATHAM.

The Fens upon the east coast, containing upwards of 60,000 acres of valuable lands extending into the counties of Cambridge, Huntingdon, Lincoln, Northampton, Norfolk, and Suffolk, are traversed by eleven principle rivers, viz.: the Cam and Grant united, the Glen, Great Ouse, Mildenhall or Lark, Nene, Nar, Welland, Wissey, Witham, and Brandon, or Little Ouse, and numerous smaller streams, bearing the drainage of the highland country through the fens, and finally discharging their waters into the wash by the outfalls of Boston, Foss-dyke, Lynn, and Wisbeach. The works that have been executed in reclaiming these fens will always furnish an interesting study for the engineer; and it is the object of this paper to give a brief epitome of the works executed for this purpose within the Great, or Bedford, Level.

The early history of the fens is involved in obscurity; but in all probability when the ancient inhabitants, the Gyrvii, held peaceful possession they were nothing like so extensive as at present; indeed, at the period of the Roman invasion of this country, it is probable that only the lower portions lying about the present outfalls, and known as Marshland and South Holland, were subject to the hurtful annoyances of the sea; and much of what, in later years, has been drained was at that time good land, well wooded, and watered; when to deprive the inhabitants of the covert of their forests the Romans felled or burned them down, as the remains of vast numbers of trees, both burned and sawn down, discovered lying at considerable depths in the Fens, testify; after the complete subjugation of the country, in the time of Agricola, its internal improvements shared the attention of its conquerors, when fens were embanked, canals dug, and roads constructed; of the latter, the remains of one extending through the fens from Denver, in Norfolk, to Peterborough, afford an excellent example



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monastic institutions, which abounded in the

rfolk, to Peterborough, afford an excellent example

of the care and industry of this people; it is at present covered, in many places, with peat averaging between three and five feet in thickness. The drains called Po dyke and Carr dyke, are supposed to have been canals designed to facilitate the passage between Roman stations, but in all probability served a like important work of drainage. The embankments are those extending round the sea coast of Norfolk and Lincoln, and probably returning up the rivers. These banks have been the subject of much controversy, and are thought by some to have been erected for pure military purposes; but, such a structure with the sea before and a marsh behind, would afford very ill accommodation for military operations; and when we consider that the Romans, brave in war, were not less renowned for their advancement of more peaceful arts, and the collateral evidences of what they accomplished in other countries, subjugated by their arms, we are assisted in arriving at their true purpose. In Italy, the drainage of the Pontine marshes had been accomplished at a very early period; and in Holland, a country closely resembling the condition of our fens, the first embanking was commenced by Drusus for restraining the inundations of the Rhine at about the period of the Roman invasion of this country; this latter work tends to confirm the opinion that these banks were erected for restraining the ravages of the sea, and to such operations the Romans gave the name of "Aggeres marini operis." To these banks the inundation of the upper portion of the level has been ascribed; for, by impeding the free influx of the tide, and preventing the speedy descent of the fresh waters, the channels decayed, probably, some time after the departure of the Romans, when the confusion that reigned and the degeneration of the people was unfavourable to the prosecution of any great undertaking; and by neglecting to maintain the works executed by the Romans the sea regained not only its former possessions, but a very considerable tract of highland country.

Now there comes the period in the history of the fens when persons, possessing peculiar notions of piety, sought the few eminences that remained, and which were thought by the superstitious to be the abodes of horrible monsters, whose chief delight it was to rack and torture the human frame, and which are the allegorical representations of the diseases peculiar to a swampy country. These solitary spots afterwards became the centres of monastic institutions, which abounded in the fens. Much was done by

these religious houses in cultivating the lands in their immediate neighbourhood; but their works were not of a very extensive character, as the condition of the fens at the period of the Danish invasion will prove. When Ely was isolated and could only be reached by means of boats, and after the destruction of the fen monasteries by the Danes, and their subsequent restoration by King Edgar, the Abbot of Ely let out his lands and caused a ditch to be cut, in A. D. 974, for describing his boundaries. After the massacre of the Danes, and their second invasion under King Sweyn in 1002, the monasteries of the fens were sought as an asylum; but were subjected to fines and other annoyances until 1017, when Canute, assuming the crown, not only greatly enriched these monasteries, but spent a considerable portion of his time in sacred exercises at Ely.

It is reported that upon one occasion when his son and servants were passing from Peterborough to Ely, they encountered great peril by reason of a storm; when Canute heard of it he was greatly moved, and caused his soldiers and servants to mark out a dyke through the fens, which was afterwards excavated. The dyke at present ascribed to Canute is that forming the boundary between the counties of Cambridge and Huntingdon. The fens at the period of the Norman conquest (1066) were still in an abandoned state. When Ely, from its isolated position, became the refuge and last great stronghold of the Saxons in this part of the country, the attack of the Normans was for a long time unsuccessful, but at length, betrayed by its own Abbott, it was captured and the fens were divided; when each proprietor for himself sought the improvement of his estate, as will appear from the operations of Richard de Rullos, Lord of Deeping, and Chamberlain of King William, who greatly improved his town by diverting the waters of the Welland, insomuch that, that which before had been nothing but bog and water, was converted into fruitful fields.

At the death of Henry II., in the year 1189, the condition of the fens had so far improved that considerable portions around Crowland, and in South Holland had become profitable, as appears from an unwarrantable seizure of the lands belonging to the monks of Crowland by the proprietors of the neighbouring estates, who ploughed up so much that the monks had not sufficient pasture for their cattle. Another proof of the improved condition of the fens is the dispute which arose between the Bishop of Ely and the Abbot of Ramsey, as to the boundaries of their properties; for

what had formerly been an inaccessible morass, was at this time changed into good land, fit for the produce of hay and corn. This dispute terminated in the year 1256, and is the only light that illuminates the dark passages in the history of the fens; it also points out that progress had been made in works of drainage—principally by the care of religious houses. From and after the time of Henry III. the history of drainage assumes a more certain character. In the seventh year of this reign, the inhabitants of Marshland, by common consent, agreed to erect that bank called Old Podyke—to defend them from the descent of the upland waters; and somewhere about this time a great alteration was made in the course of the two principal rivers passing through the fens, viz., the Ouse and Nene, which had formerly their outfall at Wisbeach; but, owing probably to the effect of the banks for reclaiming Marshland, the waters of the upper part of the level were unable to pass so readily to sea as when the rivers were unrestrained, and consequently, overflowed, and inundated the level; when, to get rid more speedily of the waters descending by the Ouse, a new river was cut from below Littleport to Rebeck, by which the great Ouse was diverted from its ancient outfall at Wisbeach into the channel of the Brandon River, or Ouse Parva, and so to Lynn. The effect of the abstraction of this large volume of water from Wisbeach Outfall naturally hastened its decay, and its channel silting up, the waters of the Nene were either diverted or found their way by a circuitous course to Salter's Lode, and so into the same channel to Lynn; and just in proportion that the Wisbeach outfall decayed, that of Lynn widened and deepened, and became a good drain, especially for the lands in that portion of the fens now called South Level; and probably to this cause may be attributed the improved condition of the fens which occasioned the dispute between the Bishop of Ely and the Abbot of Ramsey. But whilst the condition of some parts was greatly improved and benefitted, the territory of Marshland was greatly annoyed and endangered, insomuch that commissioners had to be appointed in 1287 to enquire into certain breaches of banks, whereby a considerable amount of property had been destroyed; and again, in 1293, the inhabitants of Marshland prayed to have a portion of the waters returned to their ancient outfall, and so greatly were they annoyed by them, that a commission appointed to treat their case, ordered dams to be erected in Outwell and Upwell for accomplishing this object. Repeated complaints having been made of these dams, occasioning great obstruction

to navigation and drainage, they were ordered, in the year 1330, to be pulled up. A final attempt to convey these waters to their ancient outfall was made in 1336, but proved unsuccessful. In the interval, Marshland had suffered greatly from inundations; its banks had been washed away, and the river, which had formerly been retained within banks set twelve perches asunder, had in 1324 grown to be one mile in width, and so great had become the charges for maintaining their banks, that they were unable to meet them; in this extremity they petitioned the king (Edward III), who commiserating their distress, made them considerable deduction of their taxes, but, the object sought—to confine the river within a channel sixteen perches in width—was not accomplished until Richard II. had ascended the throne in 1377. The subsequent account of this work, as far as Marshland was concerned, shows that it was attended with success.

In 1422, owing to the accumulation of waters on the upper side of the Old Podyke, the site upon which it stood had become so weak that the bank was adjudged incapable of repair, and a new Podyke was ordered to be made. After the erection of this new bank, the waters still accumulated and inundated the lands upon the upper side thereof, when the Duke of Exeter gave permission to the Archdeacon of Lincoln to make a sewer through his property, whereby relief was effected. The attention that was being given to the construction of banks at this period was the means of procuring an act of Parliament, 6th Henry VI., 1427, for the better conservation of the sea banks, which had been often neglected, to the great danger of the country; but, with all the attention that had been paid to the works of drainage, the fens, for the most part were in a deplorable state, when Haltoft obtained a commission to cause the rivers about Wisbeach and Guyhirne to be scoured, and penalties to be inflicted upon persons causing obstructions therein; notwithstanding which, no great improvement was manifested until 1490, when John Morton, Bishop of Ely, caused a drain, 14 miles in length, 40 feet wide, and 4 feet deep, to be cut from Standground to Guyhirne, its objects were to convey the Nene in a direct course to its outfall, and so avoid its crooked passage, and to restore a body of fresh water to Wisbeach outfall. Considerable improvement was effected in the lands about Wisbeach by its completion; but, owing to its extreme shallowness, it speedily grew up, and the Nene again overflowed and inundated the country,

when a commission of sewers, in 1571, ordered it to be scoured, and deepened two feet.

After the final dissolution of the monasteries, 1539, many sewers which before had been maintained by the care of religious houses, were suffered to fall into decay; and the commissioners, in 1574, found it necessary to ordain that all drains and sewers should be freed from weeds thrice every year. But so great was the apathy or indifference of the parties upon whom the duty devolved, that the work could often only be effected by threatening to visit with the penalties of the law; and in some instances distraints had to be made upon the parties for the expenses incurred in executing the work. Without any great departure from this practice, it continued until the time of James I., when the great interest the king took in the fens was the means of instilling into the commissioners fresh energy, and they ordered one, Richard Atkins, a man well acquainted with the fens, to make an examination with an auger, and they also ordered a survey to be made by William Hayward, which bears the date of 1604. The commissioners afterwards viewed the fens, which had previously been demonstrated capable of being drained, but to derive any great benefit from the undertaking, the work must be general. On this occasion the commissoners were attended by Mr. Hunt, who pointed out the works necessary for effecting the drainage, the principal point in his scheme being the construction of two rivers, from Earith to Salter's Lode, which were, at a later date, cut by Vermuyden.

So urgent was the king, and so great the interest he took in the work of drainage, that he commissioned Lord Chief Justice Popham to undertake a portion of the work, and likewise induced a company of Londoners to undertake another part.

The plan intended to be pursued by Popham was similar to that proposed by Hunt; indeed, it is probable that it was the same, as Hunt was afterwards employed by Popham in his undertaking.

The works undertaken by Popham commenced in 1605, and there still exists a drain made at this time and called Popham's Eau, as also a drain cut by the Londoners, and called Londoners' Lode after them.

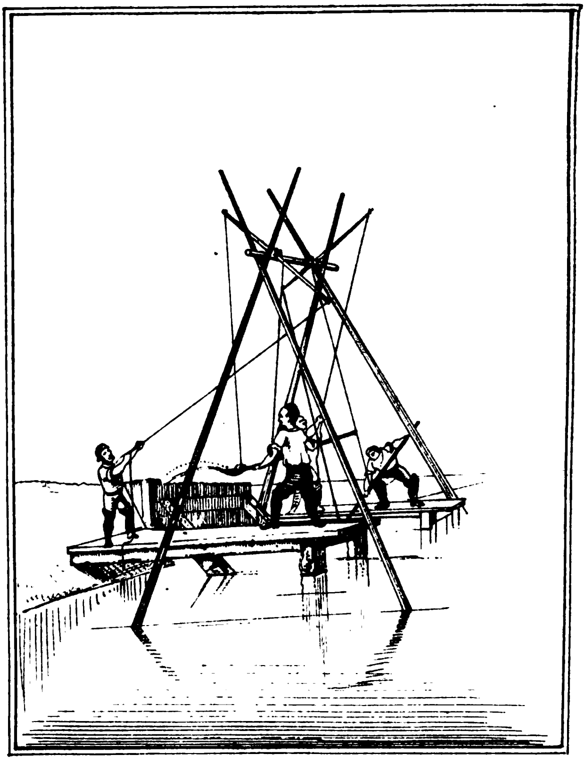
The scheme of Popham embraced the drainage of the whole level; but the state of the south level at this time was such as not to require the help of the drainer in the same degree as some other parts, hence, the number of petitions presented from this vicinity, praying to be exempted from

this undertaking; and a petition from Lynn, in 1618, praying to have the haven confined, will shew that the outfall for the waters of this portion of the fens was at this period in good condition.

The death of Popham taking place before the undertaking may have been said to have fairly commenced, the work was again delayed; but in the interval an Act of Parliament had been procured for effecting the drainage of Waldersea and Coldham, a district containing about 6000 acres.

The works of drainage had again reverted into the hands of the commissioners of sewers, but during the frequent squabbles amongst themselves, no progress was made, and at length being unable to agree upon any definite plan, they petitioned the Lords of the Privy Council, who sent down Sir Clement Edmunds, to advise them upon the matter. The subsequent effect of his report was the undertaking of the drainage by the Earl of Arundel and others, whose scheme differed from former ones, inasmuch as they proposed to commence by improving the outfalls; but owing to disputes, the works were never commenced. In the meantime, the inhabitants of the fens evinced the greatest dislike to the undertakers, and looked upon them as very little better than robbers, who would take their lands, and so deprive them of the scanty sustenance they procured by taking the fish and fowl which everywhere abounded in these dreary wastes.

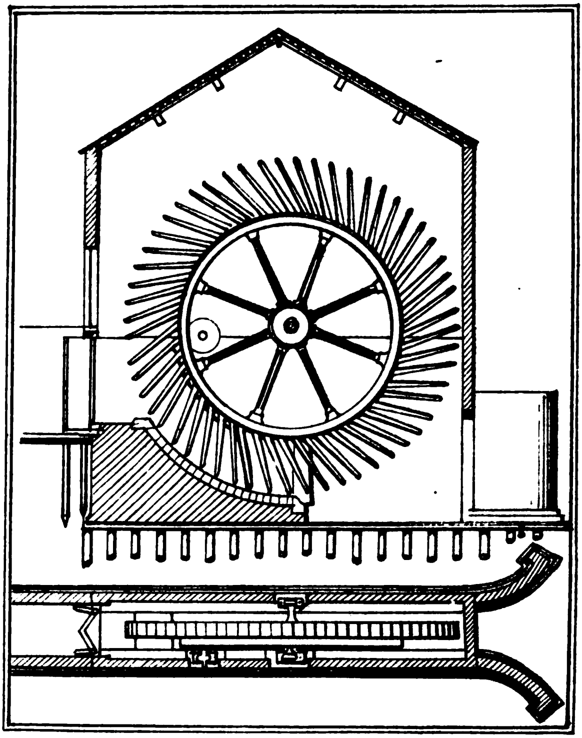
A spirit of uncertainty had seized upon the minds of the commissioners, who began to calculate whether or not they should derive more benefit from the fens if they were drained. In the midst of this uncertainty, Cornelius Vermuyden, who had been invited over into this country to stem a breach in the embankment of the Thames at Dagenham, which had been satisfactorily completed, together with the work of reclaiming Hatfield Chase, made an offer to the Commissioners of the Great Level for draining their fens; this offer met with favourable consideration; but the same opposition that had been manifested in other places against the employment of a foreigner was greatly embittered in this instance by the general opposition to drainage; so that the commissioners who had made an agreement with Vermuyden were ousted, and other commissioners were appointed, who rejected his proposals, and became suitors to Francis, Earl of Bedford, praying him to undertake the work, which resulted in a contract with the Earl, by which he was to receive 95,000 acres, to defray the cost of the works, which were to be completed in six years; and the fens were to be made good summer land, without



THE WHIP SCOOP,

An Implement Formerly Used In The Drainage of The Fens.

B. Latham, Del.



SCOOP WHEEL

USED IN THE DRAINAGE OF THE FENS

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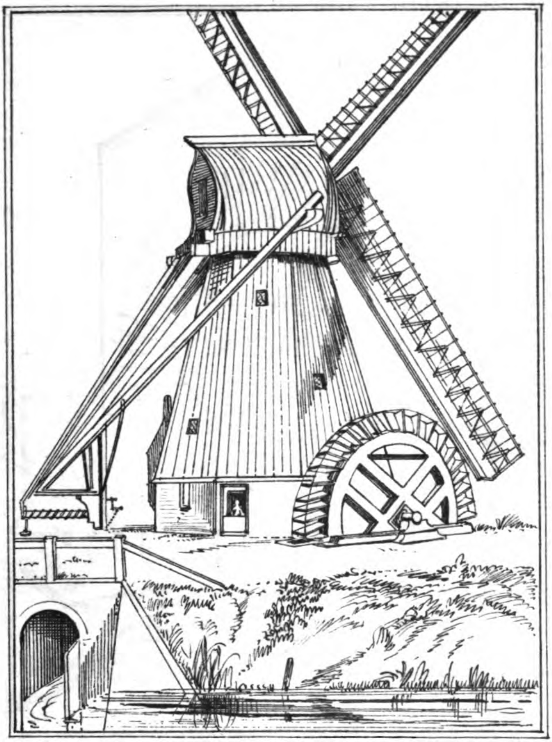

DRAINAGE MILL

BEFORE THE INTRODUCTION OF THE STEAM ENGINE INTO THE FENS

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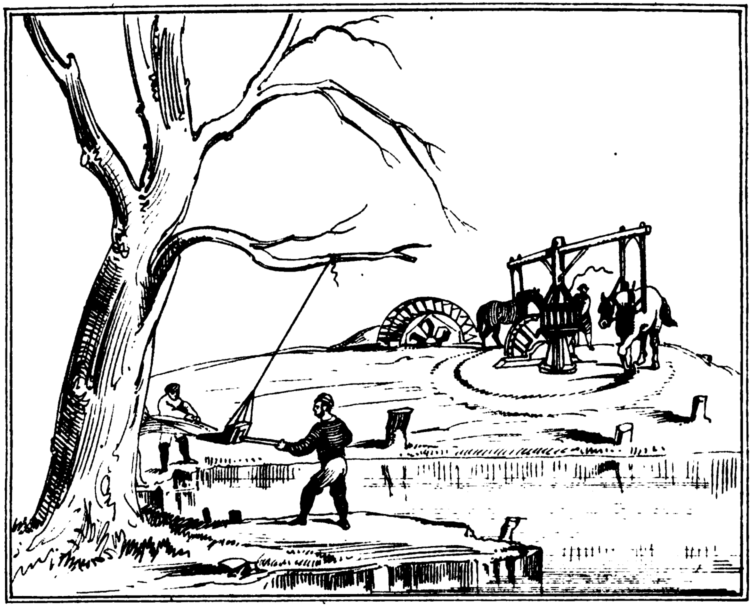


HORSE MILL AND SCOOP

AN EARLY MODE OF FEN DRAINAGE.

B. Latham Del.

predjudice to navigation. This contract was finally ratified at Lynn in 1630, and is called the Lynn Law.

Before commencing operations the Earl associated with himself other adventurers, and by an agreement, called the indenture of fourteen parts, the terms of participation were agreed upon. 43,000 acres of 95,000 were to be appropriated to the construction of the works, 40,000 acres to their maintenance, and 12,000 acres were given to the King, to procure his royal assent to the undertaking; Vermuyden was retained as engineer, and the following works were executed :—

1st. A river, 21 miles long, 70 ft. wide, extending from Earith to Salter's Lode, and now called the Old Bedford River. It had sluices at both ends, and was intended as a slacker to the Ouse.

2nd. Sam's cut, from Feltwell to the Ouse, 6 miles long, and 20 ft. wide.

3rd. Sindall's cut, 2 miles long, and 40 ft. wide.

4th. Bevill's leam, 10 miles long and 40 ft. wide.

5th. Peakirk drain, 10 miles long and 16 ft. wide.

6th. New South Eau, from Crowland to Clow's Cross.

7th. Hills cut, near Peterborough, 2 miles long and 50 ft. wide.

8th. Shire Drain, from Clow's Cross to Tidd, and so to sea; with a sluice at Tydd to hold out the tides, and a clow at Clow's Cross.

9th. Morton's Leam re-made, and a sluice erected at the Horse-shoe, below Wisbeach, to hold out the tides. A sluice was also put down at the outfall of Well Creek.

All seems to have gone on well with the work, except the unlooked for expense, which created some discomfiture; but, to encourage them in their undertaking, Charles I., in the third year of the enterprize, granted them a charter which gave them considerable independence.

In 1637, the fens were adjudged to be drained, and the lands were allotted to the adventurers; but, in the following year, the drainage was adjudged to be defective. The adventures up to this period had basked in the sunshine of royal favour, but now a complete change took place in the King's views; whatever his motives may have been, his conduct in the matter was anything but honourable. When commissioners were appointed to enquire into the state of the fens, and their condition as effected by the works of the adventurers, the king wrote to them advising them what

measures they should adopt, and offering to undertake the works himself. The result was, that these commissioners declared, according to the instructions they had received, against the adventurers, and greatly extolled the King for his princely care; who, shortly afterwards, was declared to be the undertaker, and was to receive, not only the 95,000 acres already allotted to the original adventures, but also 57,000 acres in addition, and the fens were to be made good winter lands. In 1639, Charles I. commenced operations, Vermuyden being still retained as engineer. The original adventurers were allowed 40,000 acres of the 95,000 acres, of which they became possessed by virtue of their contract, and on account of which they had incurred an expenditure of upwards of £100,000. The undertaking of the King was of a very extensive character, but, owing to the flames of civil war having been kindled, which these works in the fens in no small measure contributed to fan, it was abandoned after the following works had been executed.

1st. A navigable sluice was put down at Standground, upon Morton's Leam, which was also embanked on the south side, and the embankment was commenced on the north side.

2nd. A new river, 2½ miles in length and 60 ft. wide, was cut from the Horse-shoe to the sea below Wisbech.

3rd. A sluice was erected upon the outfall of Shiredrain, which was afterwards swallowed up in the quicksands.

The works executed by the King, in embanking Morton's Leam, offer the first example, within the fens, of large tracts of land being enclosed within the embankments forming receptacles in which, to use Vermuyden's expression, "the floods could bed." This system of providing receptacles for the floods, which was afterwards carried out to such a great extent in the future works of Vermuyden, and upon which so many controversies have arisen, was suggested from the practice of cutting the banks in certain parts of the fens and allowing the floods admission, so that the banks being relieved from hydrostatic pressure, were preserved. During all the commotion of the civil war, Vermuyden still lingered in the country, and the work of drainage occupied his attention, notwithstanding the troubles he had entailed upon himself by the losses which he had sustained in other works of this description, and the virulent opposition manifested by the inhabitants of the fens to his being employed.

A petition was presented by the original adventurers to the Long Parliament, but owing to the death of Francis, Earl of Bedford, nothing was done; and in the time that had elapsed from the abandonment of the undertaking by the King, the works that had been executed had fallen into decay; but within four months from the King's death, William, Earl of Bedford, procured an Act of Parliament—Notwithstanding, there were a great number of petitions against the undertaking, by which, in 1649, he was declared to be the undertaker; he subsequently entered upon the enterprise upon the same terms as the original adventurers. The new adventurers sought the services of Vermuyden; but before terms were agreed upon, Sir Edmund Patherické made the adventurers an offer to drain the fens, at a much less cost than Vermuyden had estimated, which resulted in his being declared director; when Vermuyden, who possessed considerable lands in the fens (which he had acquired from the former adventurers), opposed the scheme of Patherické as "being destructive to the work of draining," and Sir Edmund having delayed commencing operations, Vermuyden was appointed director, upon his own terms.

The plan pursued by Vermuyden was that laid down in the discourse he had published for the guidance of the King in his undertaking, by which the level was divided into three districts, viz.:—the North Level, terminating at the south bank of Morton's Leam; the Middle Level, extending from Morton's Leam to the Old Bedford River; and the South Level embracing all land south of the Old Bedford River; and the principles he adopted were:—

1st. The natural rivers should be conveyed upon the highest ground upon which they were found.

2nd. The land sewers should be laid in the lowest possible position.

3rd. Rivers subject to land floods should be provided with receptacles in which the waters could bed.

4th. The highland and downfall waters should be kept separate.

In 1650 the new works were commenced, when the adventurers found they had many obstacles to contend against, principally from the native population, who would not render the assistance they required, although good wages were proffered; and to expedite the work, an offer was made by the adventurers to government, which resulted in the employment of 1000 Scotch prisoners, taken at Dunbar; this number was afterwards

augmented by 500 Dutchmen, taken prisoners by Admiral Blake. The first care of the adventurers was the drainage of the North and Middle Levels, but the principal works were executed in the Middle Level. In the North Level the works of the original adventurers were restored, and the banks of Morton's Leam, commenced by King Charles, were completed. The new works now undertaken were:—

1st. A drain, 40 ft. wide, called Vermuyden's Eau, discharging into the Old Bedford River, at Welch's dam, and intended to relieve the lands below Huntingdon and Upwell from the inundations of the Nene.

2nd. Thurlow's drain, or the 16 ft. river; a cut nearly 11 miles in length, running parallel with the Old Bedford River, at a distance of about 6 miles from it, and discharging its waters into Popham's Eau.

3rd. Moore's drain, or the 20 ft. river, intended to connect Bevill's Leam with the Old Nene.

4th. Stonea Drain, near March.

5th. Hammond's Eau, near Somersham.

6th Conquest Lode, a drain in connection with the Nene, and discharging into Whittlesea Mere, which, at that time, was a pool of water, but has since been reclaimed. Improvements were also made in the course of the Old Nene, Whittlesea Dyke, and Popham's Eau. After the completion of these works, the adventurers sought, and, after some little difficulty obtained, an adjudication, by which they were awarded 58,000 acres. At the time of this adjudication, the principal work intended by the adventurers for effecting the drainage of the South Level, viz., the New Bedford, or 100 ft., River, 21 miles in length, and running parallel with the Old Bedford, at a distance of about half a mile, was in progress. The object of this river, commencing at Earith and discharging into the Ouse at Denver, was to shorten the channel for the passage of the highland waters conveyed by the Ouse; but the old Channel had still to be preserved by virtue of the saving clause, whereby navigation was not to be predjudiced. Therefore a navigable sluice was erected upon it at the head of the new river, by which the waters were diverted into the new channel. It has been a matter of surprise that so great a work should have been undertaken on account of the South Level, especially as at the commencement of the undertaking by the adventurers this level was in very much better condition than the other levels.

In this work Vermuyden introduced his favourite principle of receptacles. The banks were set back at a considerable distance from the cut, whereby upwards of 4000 acres were enclosed, which are called the washes, inasmuch as they were washed by every tide, and formed the receptacle in which the floods of winter were received. It is possible that Vermuyden introduced this system to palliate the evils arising from neglecting to improve the outfalls,—the means at his command being insufficient for that purpose—or, aware of the weakness of the material of which his banks were composed, he adopted this system to relieve them from hydrostatic pressure, inasmuch as the waters spreading over a large area would not rise so high as if retained within a contracted channel. Whatever the reason of Vermuyden may have been, it is certain that the effects had never been clearly calculated.

The washes, at first capacious, in course of time warped up; so that at the present time they have a mean elevation of five feet above the level of the fens. Owing to this elevation, their capacity greatly diminished, and they became incapable of retaining the floods, which consequently overtopped the banks, and which ultimately accelerated the artificial system of drainage by mills, now so extensively employed in the drainage of the fens.

Another, and more serious evil was—the floods brought down by the new river descended very much quicker than by the old and circuitous passage of the Ouse; and unable to pass so quickly to the outfall at Lynn, they returned up the old channel, and inundated the very lands the new river was intended to relieve. The adventurers, to get rid of this annoyance, erected a sluice upon the old channel of the Ouse, at Denver, just above the confluence of its waters with those of the new river. This sluice had three openings of 18 ft. each; its cill was set 8 ft. above the bed of the river; but after its erection no great improvement was manifested, as the waters descending by the New Bedford River over-rode the waters descending by the Ouse; the consequence being that the doors of the sluice were closed until the waters had risen sufficiently high to force their passage, and, in the meantime, the South Level suffered nearly as much as before.

The same state of things existed with the waters of the Middle Level descending by the Well Creek at Salter's Lode, which were damned back by the Waters of the Ouse below Denver. In order to get relief under the circumstances, the adventurers made a drain, called Downham Eau, or

St. John's Eau—120 ft. wide, and 10 ft. deep, with sluices at both ends—from above Denver's Sluice, and entering the river again at Stow, a point four miles nearer the outfall at Lynn. This drain only temporarily answered the purpose; for within three years its outfall silted up, and it was of no further use until 1666, when a small drain was turned into it.

To get relief for the water of the Middle Level, a similar plan was adopted, and a drain was made, called the Marshland Cut, or Tongs Drain, extending from Nordelph to a point above Stow, by which the lower outfall was procured. Both the Tongs Drain and Downham Eau were constructed without the Great Level, and at their completion the fens were declared to be drained. It soon became apparent that the latter works executed by the adventurers were predjudicial both to drainage and navigation. The channel of the Ouse rapidly decayed, especially between Denver and Stow, where it silted up level with the bed of the New Bedford River, which was originally 9 ft. above the level of the bed of Ouse. The navigators became alarmed, and petitions were presented to Parliament, praying to have Denver Sluice pulled up, as to it was ascribed the state of the river. The argument advanced by the petitioners against this sluice was, that the tides were prevented entering the large receptacles of the Ouse, Grant, Stoke, Mildenhall, and Brandon rivers, and compelled to traverse the shallow river of Bedford, whereby a sufficient ingress of tidal waters was not admitted to keep the channel clear; and the evidence they produced in support of their views was, that in 1645 the tide set into the river 5½ hours, but in 1660, after the sluice had been in operation nine years, the river silted up, and the tide set in but 3½ hours.

The decay of the river between Denver and Stow had been accelerated by the construction of Downham Eau and the Tongs drain; for by them the fresh waters had been abstracted from the channel of the Ouse; but as the outfall of Downham Eau soon decayed and was lost, the Tongs drain became the subject of much dispute; the navigators fearing that the waters in Well Creek would run so low that all traffic would be stopped, whilst the drainers saw that by the continued use of this drain, that portion of Well Creek between Nordelph and Salter's Lode would silt up, and the Ouse would lose the benefit of the scour derived from the fresh waters descending this way. To reconcile the conflicting interest, a clause was inserted in the River Nene Act, by which "that drain called Marshland Cut, or Tongs Drain

shall not at any time be run, unless upon a breach of bank, or in case of imminent danger thereof, or unless the waters of the said rivers be raised more than 1ft. above the level of the soil of the lowest lands of the fens; nor in any of the said cases without an order in writing signed by ten of the River Nene Commissioners, whereof five to be commissioners of the said Corporation of the Great Level of the Fens." It was finally agreed that when the waters should stand nine feet upon the cill of Salter's Lode Sluice, the Upper doors of the Tongs Drain should be opened. This drain, which was the lowest outfall for the waters of the Middle Level, has been entirely superseded by the new Marshland Cut, or Middle Level River, made at the expense of the Middle Level Commissioners, who received from the Bedford Level Corporation £800 per annum, and relieved them from the expense of maintaining the Tongs.

At the accession of Charles II., the adventurers, who had completed their undertaking under the powers granted by the "Pretended Act," were obliged again to appear before Parliament. A temporary measure was passed, and the King issued a proclamation against the destruction of any works within the Great Level; but so great was the dislike to the undertakers and the works of reclamation, that the adventurers had diligently to watch and guard their works, for fear the tumultous rabble (who often congregated), should destroy them, as they had before similiar works in other parts of the fens. At length an act was procured in 1663, by which the adventurers retained their powers as before.

After things were thus settled, the Corporation commenced to improve the works they had already executed. Two additional eyes were now added to the Denver Sluice, by which the waters of the South Level could be discharged more speedily. The navigators and the towns of Cambridge and Lynn, which were more particularly interested in the navigation of the Ouse, still sought the demolition of this structure. At length the tides accomplished their object, as Denver Sluice was blown up in 1713. Unlike the recent catastrophe in the fens, arising from the total destruction of the Middle Level Sluice, the foundations of this sluice remained entire, only the piers between the three original openings being swept away, and the tides and land floods again flowed up the old channel of the Ouse. To counteract the baneful effects many propositions were made, that by Colonel Armstrong being the most popular, viz., to restore the channel.

But it could not be expected that the Bedford Level Corporation, who had incurred great expenses in cutting a new river, would very willingly adopt this scheme, which would have completely revolutionized their former undertakings.

The tides and land floods carried so much silt into the river above the sluice that at low water the channel was nearly dry. In considering the facts of the case, it must be borne in mind the river at Denver before the erection of the sluice was 120 ft. in width; but the breach in the sluice did not exceed 70 ft. in width. This, together with the obstructed state of the channel below the sluice, would be sufficient to cause the decay in the upper part of the river. As a last extremity, the proprietors of lands within the South Level, together with the navigators, petitioned the Bedford Level Corporation to re-erect the sluice; when the very persons who before had been so eager to have it pulled up, were equally so now to have it rebuilt; but the Corporation did not interfere until matters were assuming a very serious crisis, when they commissioned Labelye, who in 1750 erected a new sluice upon the old foundations.

The obstructed state of the outfalls now received the attention of the Corporation, who were fast advancing towards the true and proper course to be pursued in getting rid of their waters. The first work of this nature was Kindersley's Cut, below Wisbeach, a river 2 miles in length, and intended to shorten and confine the channel of the Nene; it was nearly completed in 1721. The dams for diverting the river from its original channel having been commenced, the authorities of Wisbeach, who had before given their consent to the undertaking, fearing the result, procured an injunction by which the work was stopped at the moment of its completion. The channel still continued to decay, until vessels which had been before able to sail into the town of Wisbeach, were no longer able to advance up the river, and therefore compelled, at an additional cost, to discharge their freight into lighters, by which it was conveyed into the town. This work was eventually done after the lapse of fifty years, during which period the trade of Wisbeach had gradually declined, and at length, when their condition became desperate, they no longer opposed the undertaking.

In the works executed by the Corporation it was often found necessary to empty a river or drain, and to faciliate these operations, the Corporation ordered in 1687 each of the Superintendents of the different levels to

purchase mills, by which the work could be more easily performed, which before had been effected by scoops, so constructed as to be worked by a number of men. The mills ordered by the Corporation consisted of a wheel with floats, very similar to the old breast wheel, and to which motion was given by horses; and so the waters were raised upon the principle, that any machine impelled by water, and from which power may be derived, will, if reversed, raise a column of water.

The great improvements that had been made in the condition of the fens, by the works of the adventurers, by which they had been made good summer lands, had generated the idea of further improvement; and the introduction of mills into the works of the Corporation gave rise to their application to effect this improvement. In the records of the Bedford Level, it is found that in 1699 a person of the name of Green, erected a mill at Slade, and in 1703 another mill was erected at Ramsey, by Sylas Tytus, Esq., both these mills were declaired to be nuisances and ordered to be pulled down. The great complaint against them was, that with the waters, they raised silt and other matter, which choked the drains, whereby the adjoining lands were inundated, and draining was predjudiced.

Although the first mills were opposed, popular opinion had made such advancement in their favour that they soon took their place as absolute necessaries in the economy of drainage. The cause that had accelerated their introduction was: the porosity of the river banks, which being constructed principally of moor, in a few years decayed and became pervious; another cause is set forth in a petition, dated 9th April, 1726, from the inhabitants of Haddenham to the Bedford Level Corporation, in which the state of the 100 ft. river and washes is mentioned as being unable to retain the floods, which had overflowed the banks twice within the last year, and they prayed to be allowed to introduce machines to relieve them of the waters. After this petition the Corporation found it vain, any longer to resist the demands for internal drainage, and in the following year an Act of Parliament was procured for the effectual drainage of Haddenham Fens by the use of mills. Their introduction into other districts followed in a train of quick succession, until at length their use became general. The wind was the propelling power of these machines; but it often happened that a heavy rain was followed by a dead calm, and by reason of the

accumulation of waters, the works of the agriculturist were either destroyed or his operations delayed, so that a great boon was conferred when Rennie introduced the steam engine as the motive power of the scoop wheels. In modern wheels of this description the floats are set at an angle of about 50 deg, and the wheels are driven at a speed of about six feet per second, but there is at the present time a disposition, far from economical, on the part of some of the district commissoners to increase the speed of their wheels. Since the introduction of mills and more perfect drainage, the surface of the fens has subsided some feet, insomuch that an increased power has become necessary on account of the greater elevation to which the waters have to be raised; but where no extra power may be required, the wheels have to be lowered.

The subsidence of the peat, which composes the soil of the fens, has brought within reach the gault or Kimmeridge clay, a material used by the farmers as a fertilizer, which gives consistence to the light lands of the fens, and is valuable to the drainer as a material for the construction of banks or the manufacture of puddle.

The division of the fens into three levels by Vermuyden engendered the idea of separate interests, which, after the completion of the drainage, was not long in ripening into a reality; the great expense of the North Level works and the frequent disasters, often occurring in this district, had saddled considerable liabilities upon the corporation; when its separation was determined, first by agreement, but afterwards by an Act of Parliament in 1753, by which the commissioners of the North Level retained in general the same right at the meetings of the corporation; except that in all matters of a financial character their powers were exclusively confined to their own level. Within the last few years the separation has been entire, and the jurisdiction of the Bedford Level Corporation is confined to the Middle and South Levels; but, from and after April 1863, the power of the corporation will cease in the Middle Level, by virtue of an Act procured during the last Session of Parliament.

The great success that had attended the opening of Kindersley's Cut, below Wisbeach, was the means of agitating the subject of executing another cut proposed by Kindersley near the outfall of the Ouse, by which it was to be diverted from its winding course into a straight cut from St. Germains to Lynn. It was contended by Kindersley, the projector of this cut, that the bad state of the river Ouse was not so much owing to the erection of Denver

Sluice as to its shallow channel so near its outfall; yet the inhabitants of Lynn, who had been so vehement in their complaints against the sluice, would not listen to the making of this cut, called the "Eau Brink Cut," fearing, as the authorities of Wisbeach had done before, that the confinement of the channel would be attended with the ruin of the harbour. The good opinion entertained by engineers, of the benefit that would accrue both to navigation and drainage, at length prevailed; and an Act of Parliament was procured in 1795, for its construction; but so great had been the opposition manifested against the bill, that the legal expenses swallowed up nearly all the funds that were available for the execution of the work. This cut was eventually made in 1821, by the Eau Brink Commissioners, in whom the channel of the Ouse, from Denver to Lynn, was also invested. The new cut commences about ten miles below Denver, and was excavated to a depth of eight feet below the cill of old Denver Sluice. Soon after its opening it was found that its capacity was not sufficient, and in 1826 its area was increased at a cost of £33000. A new sluice was erected at Denver by the same Commissioners, the cills of which were set six feet three inches lower than those of the old sluice. The cost of executing these works was borne by the Middle and South Levels and Marshland. But by an Act of Parliament procured in 1860, called the "Ouse Outfall Act," the Eau Brink Commission was dissolved and their powers invested in two bodies, viz., the Ouse Outfall and the Denver Sluice Commissioners; the jurisdiction of the latter body extended from Denver to the Eau Brink Cut; that of the Ouse Outfall Commissioners from that point to the sea. Each of these commissioners had power of taxation over all lands draining through their channels. The object of this bill was evidently to relieve the Middle Level from contributing to the maintenance of the channel of the Ouse from Denver to the Eau Brink Cut; for by the construction of a new river by the Middle Level Commissioners, they had ceased to use the outfalls of the Tongs and Well Creek; but owing to the recent destruction of their outfall sluice upon this river, they have been obliged to revert to their old outfall at Well Creek.

Under the authority of the Eau Brink Commissioners Act, the Bedford Level Corporation were obliged to effect considerable improvements in the 100 ft. river. A cradge bank was erected on the north-west side thereof, by which ordinary floods were retained within the channel; in winter this bank was cut, and the water allowed to enter the washes; but this barbarous

practice has since been superseded by the erection of sluices, by which the waters are admitted into the washes when required. The effect of these improvements has been that the channel of the Eau Brink Cut has been deepened six feet by the improved scour, and low water mark has been lowered seven feet. A more marked improvement has been manifested in the Wisbeach outfall by the prolonging of Kindersley's cut under the authority of the Nene Outfall Acts, by which low water mark has been lowered nearly eleven feet, so that lands, which before were unable to drain except by artificial means, can now procure a good outfall for their waters.

After the great improvements in the outfalls, the Middle Level Commissioners determined to make some improvements in their internal drainage. Rival plans of adopting the outfall by Wisbeach or by Lynn were discussed, and eventually the outfall by the Ouse was determined upon. A cut joining the 16 ft. river, and called the Middle Level River or Marshland New Cut, was made under the direction of Walker, in a direct line to the Eau Brink Cut; and a sluice was erected at its outfall. This river was opened in 1848, and continued to give satisfaction until the present year, when its sluice became undermined by the tides and fell; and as its embankments were only calculated for the conveyance of waters at a low level, they were unable to bear the pressure, brought to bear upon them by the tide reverting up the river; the consequence was, the bank failed and inundated upwards of six thousand acres of land, lying within the territory of Marshland.

The comparative result of artificial and natural drainage may be arrived at from the amount of taxation; in the Middle Level, with a natural system of drainage, the tax amounts to 4s. 6d. per acre, but in the districts of Sutton and Mepal, which stood aloof from the Middle Level in their undertakings, the tax is but 1s. 6d. per acre, and they are at all times masters of their water.

The labours that are now being prosecuted, for improving the channel below Lynn, will, when completed, have a good effect upon the works of drainage; but much remains to be done in the channel of the Ouse between Denver and Eau Brink, the obstructed state of which may be arrived at from the fact that, whilst the inclination through the Eau Brink Cut is only four inches per mile, the inclination above this point is fourteen inches per mile.

December 1*st*, 1862.

C. L. LIGHT IN THE CHAIR.

ON THE INUNDATIONS OF MARSHLAND.

By BALDWIN LATHAM.

The inundations of Marshland during the present year have been the means of attracting attention to the great works of drainage that have been carried out in the Fens of this country, by which large tracts of the most valuable land have been recovered. The history of the drainage of the Fens will show that the works of reclamation were fraught with much difficulty; great courage and perseverence having been exercised before they were brought into their present condition. Often have works that have cost much labour and expense been swept away before the fury of the raging sea; but as often these failures have been succeeded by renewed efforts at reclamation. The district of Marshland has been more particularly affected by the ravages of the sea; time after time have its banks been swept away, and the country far and wide laid desolate. The recent inundation is another to add to the number gone before, and it will be the object of this paper to give a brief account of this inundation, the means adopted to debar the entrance of the tidal waters, and the method of discharging the fresh waters, together with some observations on the cause of the disaster, and the principles of fen drainage. The territory of Marshland, lying between the two great outfalls of Lynn and Wisbeach, was at a very early period recovered from the sea. A geological examination of the strata composing its surface, will show that after its first reclamation it was overflowed by the sea; then followed a period when its banks must have been perfect, but still it was subject to inundations, not from the sea but from the descent of the fresh waters, as a bed of peat (a fresh water deposit) extending over the whole territory will prove; and this again must have been succeeded by another eruption of the sea. The effect of these successive inundations has been to raise the surface, principally by the warp, some ten or fourteen feet higher than at the time of its first reclamation.

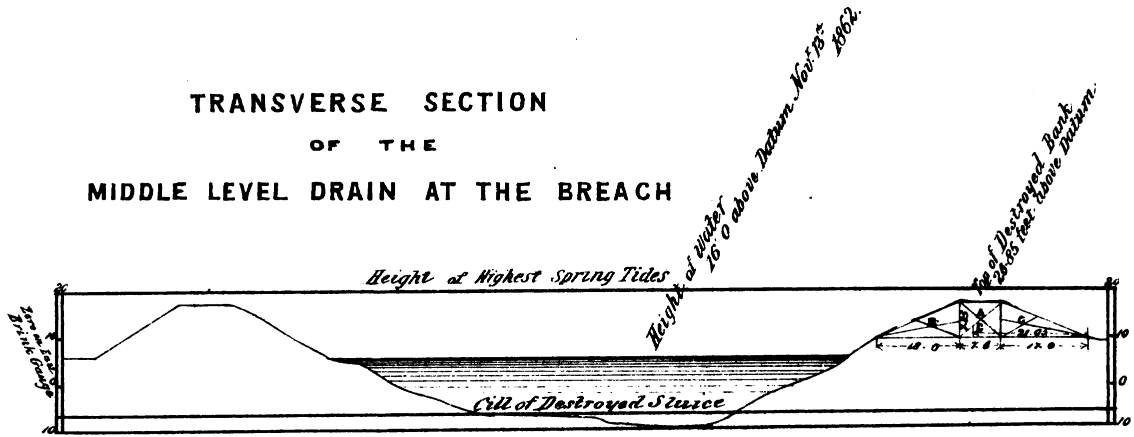
The drainage of that portion of the district affected by the recent inundation is effected partly by the natural descent at low water, and partly by

steam power: the waters are conveyed into the river Ouse near the head of the Eau Brink Cut by two drains running parallel at but a short distance apart; one drain is called the Marshland Smeeth drain, the other Marshland drain: both these drains have sluices at their outfalls to hold out the tides. At a short distance above the Smeeth sluice is the outfall of a drain running through Marshland, but from which it derives no benefit; it was made by the Middle Level Commissioners, and opened in 1848; this drain is about eleven miles in length, and joins the 16 ft. river (a drain in the Middle Level made by the adventurers in 1650), from which it is continued in a straight line to near the top of the Eau Brink cut. The object in excavating this drain was to get a nearer and lower outfall for the waters of the Middle Level. Great opposition was manifested to its construction by the inhabitants of Marshland, but the bill authorizing the work was eventually passed with the addition of certain protective clauses inserted at the instance of the inhabitants of Marshland. Section 137 of this bill provides that the Middle Level Commissioners "shall, where necessary, make and maintain in a sub-" stantial manner a bank on each side of the said cut, with front and back " forelands thereto, and each of the said banks shall be constructed with a " good and sufficient puddle clay wall in or near the centre of such bank, of " proper depth, width, and height, and dimensions, so as to effectually defend " the lands lying on each side of the said drain from the passage of water " through the said banks at all times." Section 138 makes provision for the construction and " maintenance of a good and substantial sluice of bricks and " stone at or near the entrance of the said cut into the river Ouse, with two " or three openings, the waterway of which shall not be altogether less than " 50 feet, and with doors to each of the said openings of sufficient height to " exclude the tidal waters; and the cill of such sluice shall be placed not less " than six feet below datum." The great fear of the inhabitants of Marshland was that the fresh waters would accumulate in time of flood in this drain faster than they could be discharged at low water, hence the above clauses. As originally constructed this drain had a bottom width of 50 feet; its bed was three feet below datum or zero upon the guage at the Eau Brink bridge, which is the standard for all observations in the fens draining by the Ouse, and it had an inclination of one inch per mile. A sluice of brick and stone was erected at its outfall, the cills of which were placed according to the Act of Parliament six feet below datum. This sluice had three openings each of twenty feet, with pointed doors upon the sea side, these doors were

TRANSVERSE SECTION

OF THE

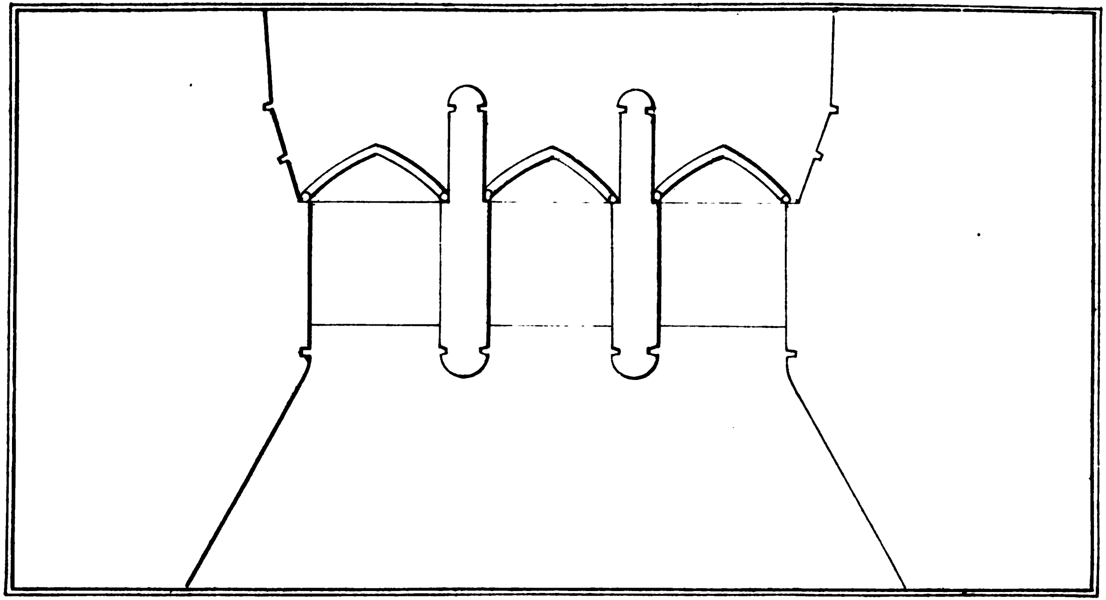
MIDDLE LEVEL DRAIN AT THE BREACH



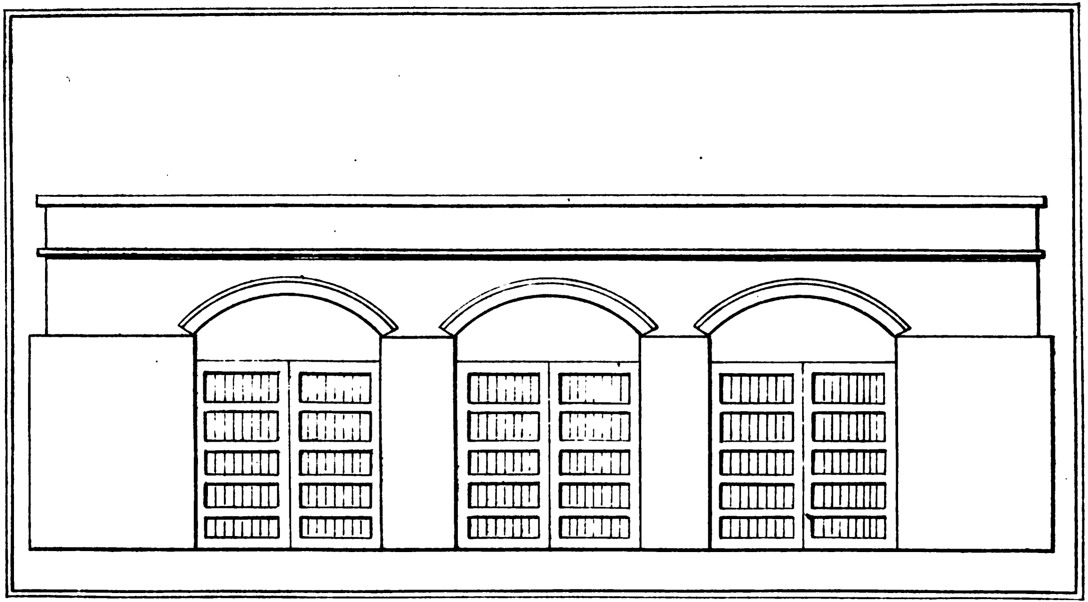
Datum 10 feet below Zero on Eau Brink Gauge

Scale 40 feet to an inch.

B Latham Del.



PLAN OF THE MIDDLE LEVEL SLUICE (B. Latham Del.)



ELEVATION OF THE MIDDLE LEVEL SLUICE (B. Latham Del.)

19 ft. 6 in. in height, but as the spring tides rise this height above datum or six feet above their tops, the upper portion was protected by a fixed hood of cast iron against which the doors closed. The sluice was built upon a platform of timber supported upon piles. The nature of the foundation is a quicksand, and it is probable that this sluice and those of Marshland were built upon a portion of the old channel of the Ouse, which is a river that has been subject to various changes in the course of its channel from time immemorial. The nature of the foundation of this place was understood at least two centuries ago, when Colonel Dodson proposed a scheme for draining the fens and improving the outfall at Wisbeach, the main features of this scheme being the erection of a sluice across the Ouse near the present outfall of the Middle Level drain, and the formation of a drain through Marshland, by which the waters of the Ouse were to be conveyed to their original outfall at Wisbeach. This scheme was opposed not only on account of the damage that Lynn would have sustained, but on the ground that the sluice was proposed to be erected upon a quicksand: and as the whole scheme depended upon its stability, it would be very likely to prove a failure. After the Middle Level drain had been in operation a few years the Middle Level Commissioners deepened all their interior drains; when, to derive full benefit from this work, they deepened this drain four feet so that its bed was lowered to one foot below the cill of the outfall sluice. The drain was still the same width, viz., 50 feet in the bottom with side slopes of 2 to 1, and the original but slight inclination of the bed was superseded by a perfectly level bottom. Until March last all seems to have gone on well, but at the latter end of that month it was observed that certain holes had made their appearance in the bank at the back of the wing wall on the east side of the sluice, and cracks were discernable in the arches which carry the roadway over the sluice, and which opened and closed with the rise and fall of the tide. The holes were filled up with puddle, which was supposed to have been sufficient to effect a cure, but how successful the sequel will tell; six weeks elapsed when it was again found that the bank next the wing wall of the sluice was being undermined, and with it a portion of the foundation of the sluice. On the 3rd of May several loads of earth were tipped into the holes; this speedily disappeared, and on the following day the whole surface of the bank next the wing wall subsided 15 feet, showing to what a serious extent it had been undermined, thus making a breach some 20 to 30 feet in width, through which the rising tide swept with great force. Efforts were made to stop the breach with earth

and straw, but the tide swept all the materials away, together with the wing wall of the side of the sluice which had been partially undermined. The tides now advanced up the cut, and so great was the scour of water through the breach that the whole of the foundation of the east portion of the sluice was speedily destroyed, and the same evening the structure fell in. After the total destruction of the sluice attempts were made to construct a dam of earth across the drain to prevent the ingress of the tidal water, and large quantities of earth were excavated from the side of the banks and thrown into the drain but with little effect; consequently this method was soon abandoned and recourse was made to sinking barges loaded with earth and clay, and piling upon them bags of clay, but to no purpose. In making the attempt to form this dam sacks of clay had been built into a bank and extended from both sides of the drain, but the work advancing quicker on the east side than on the west the increased scour upon the west side brought down a large portion of the bank; and after much time and material had been wasted in the ineffectual efforts to form this dam, an attempt was made to form a dam at St. Mary's bridge by driving piles. For two days this work had been prosecuted, when one of the barges that had been sunk in the attempt to form a dam nearer the destroyed sluice, was carried by the tide with such violence against this dam that it completely swept it together with the bridge away. In the time that had been spent in making these fruitless efforts to stop the entrance of the tides, the banks of the drain began to show signs of failure; being lower than high water at spring tide, in some places the water overtopped them; in others the leakage through became perceptible; great and by no means groundless fears were entertained of their stability, for it is a sure sign of imminent danger when the water is seen to pass through a bank; these fears were soon realized, for on the 12th May the west bank, at a point about two miles above the destroyed sluice, gave way. This rupture was effectually closed with bags of clay and puddle, but whilst the operation of this bank was being completed another rupture took place about one mile higher up, which was of such a formidable character as to render the task difficult of successfully closing it until the tides had been prevented entering the drain. Other reasons operated powerfully for not attempting to close this breach; the general state of the banks was such that could this breach have been closed in all probability it would have been attended with failures of the banks in other places, and although the general effect of the breach was prejudicial to

THE MIDDLE LEVEL SLUICE AFTER ITS DESTRUCTION (B. Latham, Del.)

the work of forming a dam near the destroyed sluice, as it caused a much larger influx of the tides to enter the drain than otherwise would have taken place, and the ebb waters rushing back through the breach greatly endangered the opposite bank, yet as it acted as a vent for the waters confined in the drain, to it may be ascribed the salvation of a very much larger tract of land in which the Middle Level Commissioners were more particularly concerned. After the failure of the pile dam at St. Mary's bridge two dams were commenced, one a coffer dam, the other a dam by "Muller," a Dutch engineer, consisting of cradles made of brushwood bound together with withes; each cradle was long enough to reach across the drain, and when complete was floated over its intended site and sunk with bags of clay and stone thrown in from barges; one cradle after another was thus intended to be deposited until a solid wall reaching above high water should have been raised.

The first attempt to sink the cradles was a failure; yet, afterwards, the work progressed so far that at low-water there was a considerable fall over the site of the dam; it now appeared clear that if this dam was allowed to proceed at the same rate it had heretofore advanced, it would hold up the ebb; so that the effect would be to increase the depth of water upon the inundated lands, and consequently greatly to extend the amount of damage already done; so its construction was wisely discontinued, and the formation of the coffer dam alone proceeded with. Two things were requisite for a dam that should prove successful: first that the channel should not be unduly contracted during the time of its formation, and so prevent the scour which would otherwise take place; and secondly, that it should be speedily constructed, or the extent of the inundation would probably be increased.

To meet the emergency of the case, Mr. Hawkshaw, the engineer for the work, devised a very simple, and which afterwards proved a very effective dam. Two rows of close piling, 25 ft. apart, were commenced at the banks of the drain, and extended about 40 ft. at each side, having a space of over 90 ft. in the centre. In this space twin piles were driven at rather over 7 ft. apart, a space was left between the piles of 8½ inches, which formed a groove in which it was intended to insert panels, when the whole of the frame-work was complete. To insure the parallelism of these grooves, to one of the piles a batten was spiked before driving, and the next pile driven down close to it;

the piles used in this work were 14 inches square, and about 40 feet in length. The two walls of the dam were securely tied together; each wall had inside and outside walling-pieces, both at the top of the dam and at 15 ft. from the bed of the river. The dam was further secured by struts, extending from the shore at each side and meeting on the wallings near the centre of the dam. The abutments for these struts were formed by eighteen piles, driven in rows of six, one row behind another, and well backed up with concrete. As the piling advanced, a gallows frame was erected over each side of the dam, and a staging thrown out from it, from which materials were continually thrown into the channel, to preserve, as far as possible, the integrity of its bed. As a further precaution, to preserve the bed of the channel, the edge of the bottom panels was sharpened, and the panels driven into the bed of the river. The panels consisted of squared timber, bolted and strapped together.

On the 10th of June the dam was so far completed that an attempt was made to close it.—The panels were swung from the gallows frame into position, and when in place were about 24 ft. in height. After the last panel had been lowered, it became obvious that the dam had blown, and upon subsequent examination it was found that several of the piles had been fractured. To prevent any further mischief, the whole of the panels down to low-water mark were immediately raised, and the tides again advanced up the drain. The cause of the fracture of these piles has been ascribed by some to the damage they sustained in driving; by others it is thought that the panels did not fit properly into the groove, and consequently, were forced out, and that the great pressure the water exercised upon the partially liberated panels was the immediate cause of fracture. This seems to be very probable, especially when the number and position of the piles is taken into consideration. The head of water at the time of fracture was 7 ft.

After this fracture some slight alterations were made in the mode of carrying out the work, and the ties between the front and back walls of the dam were strengthened. Nine days after the first unsuccessful attempt to close the dam, another and successful one was made. After the panels had all been lowered into position, and had been examined by divers, who reported all was right, the dams became the scene of the greatest activity; load after load of puddle, which had been before prepared, was tipped into the dam from the side staging; at the same

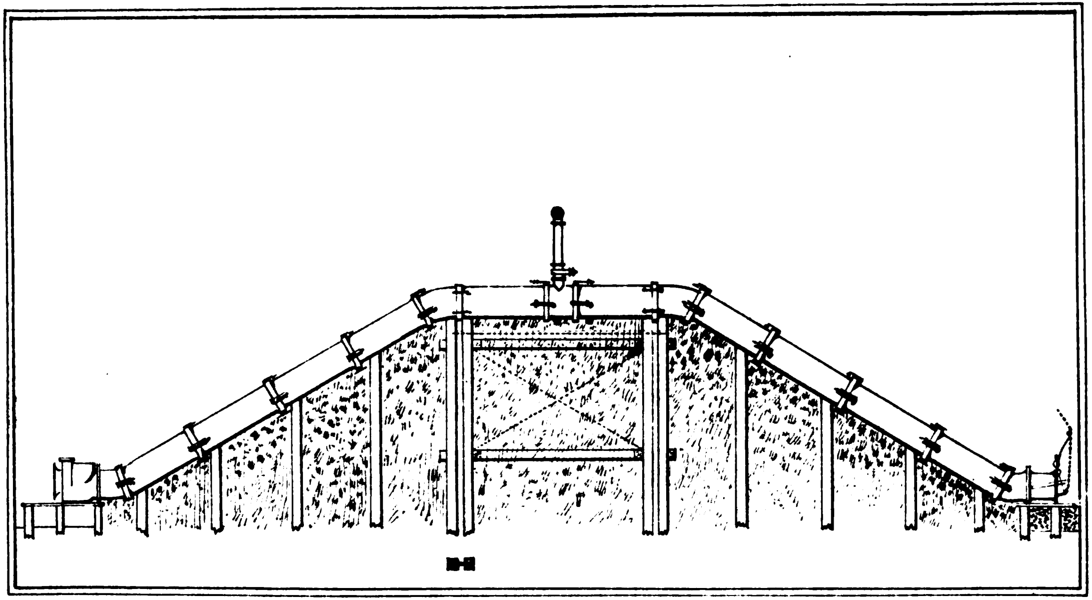
time, barges loaded with chalk and stone deposited their freight at the outside foot of the dam. The tides were then intercepted, and the dam was afterwards further strengthened by a deposit of chalk and puddle on the exterior faces, forming slopes of about two horizontal to one vertical. After the completion of the dams, the means of getting rid of the fresh waters was next to be considered. How it could have been best accomplished is a subject open to much dispute. The original outfall by Salter's Lode Sluice for the Middle Level waters still remained, but the outfall in use before the formation of this dam, viz., the Tongs Drain or Marshland Cut, had been abandoned; its outfall sluice, which originally had two openings of 16 ft each, had been pulled up, and the site of the drain sold. The outfall sluice at Salters Lode has but a 15 ft. waterway; when this is compared with the 60 ft. waterway of the destroyed sluice, or the 32 ft. waterway of the Tongs Sluice—which proved insufficient to prevent flooding in winter—it may be clearly seen that if some other method were not adopted of getting rid of the water, in all probability, the Middle Level would be flooded; besides, low-water mark at Salter's Lode, which is 9 miles higher up the river is from 8 to 10 ft. higher than low-water at the destroyed sluice; consequently, the water, to pass that way, must rise in the main drains. The regulation water at the destroyed sluice was 5 ft. above datum, and in wet seasons this would rise to 8 ft. between tides; with the water at this level, perfect natural drainage for all the lands in the Middle Level could not be accomplished, as some lands are about from 7 to 9 ft. above datum, others rising from 12 to 14 ft., whilst the higher districts have but little need of artificial means to get rid of their waters; the greater portion of the level has to be assisted by steam power.

Since the making of the Middle Level Drain, the water in the main drains has been lowered, and, to suit the diminished heads, the drainage wheels have been altered, and in some instances they have been entirely abandoned. Since the completion of the works of internal drainage, the waters pass more speedily into the main drains, and it is important that they should be conveyed away as quickly as possible; up to the present time a portion of the waters of the Middle Level have been sent by the Salter's Lode Sluice, and Well Creek has been scoured, to facilitate the discharge this way; but as this outlet would be utterly incompetent to convey all the waters in wet seasons, and as the outfall sluice could

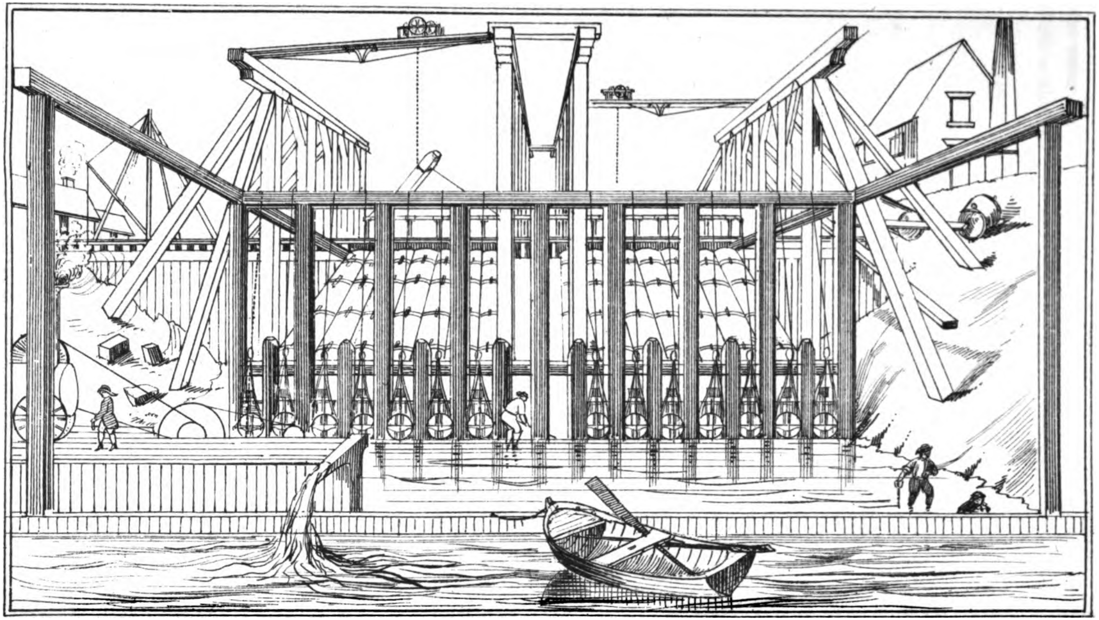
not be expected to be restored in anything like time for the winter floods, Mr. Hawkshaw proposed to carry a portion of the water over the dam by means of syphons, which proposition was carried into effect. These syphons are 16 in number, each 150 in length, and 3 ft. 6 in. in interior diameter; they are formed of socket pipes jointed in lead and supported upon a terrace of piles driven into the slopes of the dam. They are so constructed that the water enters and is discharged in a direction parallel with the drain; at the foot of the syphons on each side of the dam there is an apron of timber, secured to piles; the space between the heads of these piles has been excavated, and, on the sea side, filled in with concrete, on the river side with puddle, in each syphon there are four bends of an angle of 27 deg., and at each side there is a "Tankard Valve," to prevent the water passing back into the drain at the rise of the tide. In the centre of the dam a 9 in. pipe enters each syphon, and is furnished with a stop valve; it connects the syphons with an elevated pipe running transversely over them, which is connected with three air pumps, in an engine house on the west bank, by which the syphons are exhausted of air, an operation at all times necessary before they can be worked. The syphons are so arranged that one or more may be exhausted at the same time; the air pumps are 15 inches in diameter 18 inches in stroke, and are worked from a three-throw crank, impelled by a ten-horse engine, manufactured by Messrs. Easton & Amos. It will be requisite that the pumps should always be ready for work—if not kept slowly to work—during the action of the syphons, as the large amount of air in the water, especially in the winter months, being expelled by the motion through the pipes, would accumulate in the upper part of the syphons, and greatly interfere with their action.

So long as the syphons are entirely exhausted of air the discharge from them would equal that through a bent pipe, and may be thus arrived at:—first, by ascertaining the velocity the water would enter the syphons; secondly, by calculating the head to overcome the resistance in the bends with this velocity; and lastly, by calculating the discharge under the head diminished by the resistance of the bends. The velocity the water enters the pipe may be assumed to be the same that it would acquire under the same head through a straight pipe of equal length and diameter, example:

The water on the upper side of the dam being 6 ft. above datum or



SECTIONAL ELEVATION OF THE DAM & SYPHONS IN THE MIDDLE LEVEL DRAIN (B.Latham Del.)



VIEW OF THE SYPHONS AND DAM WHEN UNDER CONSTRUCTION. (B. Latham Del.)

zero, the water on the sea side being at zero; required the quantity that would be discharged per minute by the sixteen syphons.

First.—The volocity per minute $= \dfrac{2356\sqrt{d^5}}{\sqrt{\frac{l}{h}}\,(d^2 n)}$

where d = diameter of the pipe

l = length of do.

h = head of water

n = the ratio of a circle to a square = ·7854

$$= \frac{2356 \times \sqrt{3{\cdot}5^5}}{\sqrt{\frac{150}{6}}\,({\cdot}7854 \times 3{\cdot}5^2)}$$

$$= \frac{53975{\cdot}96}{48{\cdot}10575}$$

= 1122 feet per minute

or 224·4 inches per second.

Secondly—The head in inches to overcome the resistance in the bends

$$\frac{v^2 \times \text{sine}^2 \times \text{no of bends} \times {\cdot}0003}{\sqrt{\frac{d}{4}}}$$

where v = the velocity in inches per second

$\frac{d}{4}$ = the hydraulic mean depth in feet.

$$\frac{224{\cdot}4^2 \times \text{sine } 27^{\circ 2} \times 4 \times {\cdot}0003}{\sqrt{\frac{3{\cdot}5}{4}}}$$

$$= \frac{224.4_2 \times {\cdot}45399 \times 4 \times {\cdot}0003}{{\cdot}935}$$

$$= \frac{12{\cdot}454}{{\cdot}935} \text{ or } 13{\cdot}32 \text{ inches, or } 1{\cdot}11 \text{ feet.}$$

therefore the head under which the discharge will take place

$$= 6 - (1{\cdot}11 + {\cdot}083) = 4{\cdot}8 \text{ ft.}$$

·083 being the head to overcome the resistance of the valves, consequently the quantity discharged per minute by the 16 syphons will equal

$$\frac{{\cdot}2356\sqrt{3{\cdot}5}}{\sqrt{\frac{150}{4.8}}} \times 16$$

$$= \frac{53975{\cdot}96}{5{\cdot}59} \times 16$$

$= 154480$ cubic feet

$= 965500$ gallons.

The quantity of water capable of being discharged per minute by the destroyed sluice under the same circumstances will equal the area of the water

way multiplied by 450 and the square root of the head. As the cill of the sluice is six feet below zero the waterway would be 12 feet in depth and

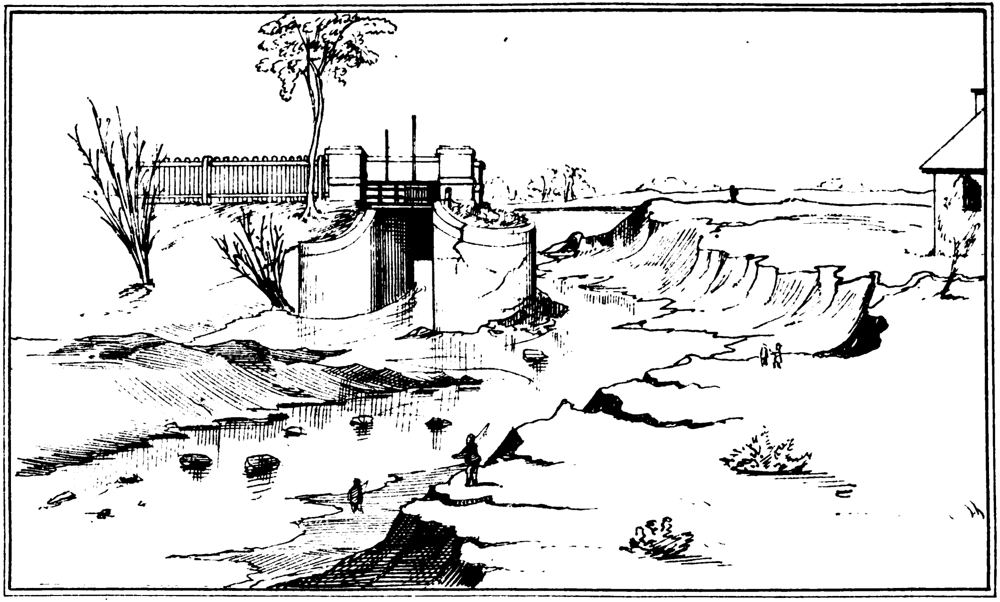
$$12 \times 20 \times 3 = 720 \text{ feet the full area of the waterway}$$
$$720 \times 450 \times \sqrt{6}$$
$$= 793800 \text{ cubic feet}$$
$$= 4961250 \text{ gallons}$$

or rather more than five times the quantity capable of being discharged by the syphons.

If merely horizontal pipes with outfall valves had been laid upon a suitable platform in the bed of the river nearer the site of the destroyed sluice, and a bank afterwards formed over them, with the same size of pipes the discharge would have been greater, and being self-acting, the constant expense attending the working of syphons would have been unnecessary and the danger attending the silting up of that portion of the drain between the syphon dam and the river Ouse in the summer months (when there will be no discharge to scour the channel clear) would have been avoided. Any system of pipes is unadvisable as a permanent work in fen drainage, inasmuch as the flows of ice descending the drains in the winter months cannot be discharged, and consequently will very speedily accumulate and stop all drainage, unless special provision is made to prevent it.

The author next enquired into the causes that led to the destruction of the sluice and the failure of the banks of the drain, but before entering on this part of the subject, mentioned that since the destruction of the Middle Level sluice, a very similar accident has happened to the Smeeth sluice, but the sluice itself was left standing. The bank on the east side was undermined and failed under exactly similar circumstances to that of the bank adjoining the Middle Level sluice. These sluices are situated upon a bend in the river Ouse, and being built upon its concave bank were more particularly liable to the effects of scour, and to this cause, together with the reputed bad foundation, may be ascribed the failures; for since the completion of the works in the estuary below Lynn, the channel of the river Ouse has been deepened and its banks greatly damaged by the increased scour.

The stability of banks is a subject deserving especial attention; great care is required in their formation, and constant vigilance need be exercised to guard against accidents. The failure of a bank may take place from either progressive or rotary motion: its resistance against progressive motion will equal $f\,(w+p)$



MARSHLAND SMEETH SLUICE AFTER ITS DESTRUCTION. (B. Latham Del.)

Where, f is a co-efficient for friction,

w the weight of the bank,

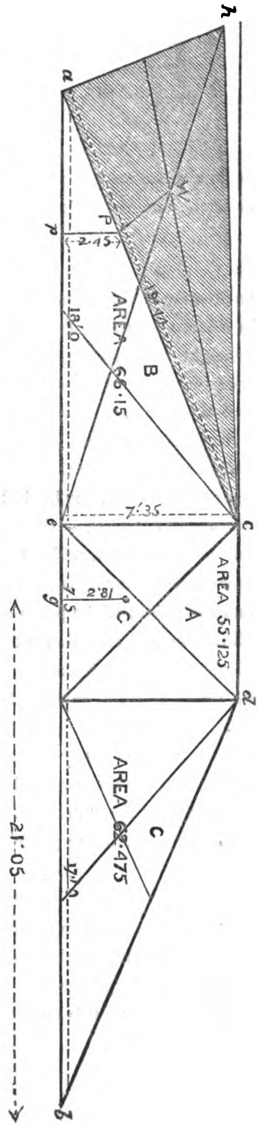
p the vertical pressure upon it.

Against the tendency to be overturned the resistance will equal the weight of the bank multiplied by the distance of the centre of gravity from the point of rotation measured upon the base line in the following diagram which shows a section of the Middle Level bank at the breach; it is required to ascertain its resistance to a force tending to overturn it on the point b as a centre; and the moment of pressure exerted against it when the drain is full: the weight of a cube foot of bank being 113 lbs. and of a cube foot of water in the drain at the time of the breach being 63·14 lb. It will first be necessary to find the position of the centre of gravity of the bank; for that purpose it may be divided into the parallelogram A and the triangles B and C. Having found the centre of gravity of each of these figures, the common centre of gravity G may next be found: its distance on the line a b from the centre b will equal g b =

$$\frac{\mathrm{A}\,d+\mathrm{B}\,d'+\mathrm{C}\,d''}{\mathrm{A}+\mathrm{B}+\mathrm{C}}$$

where A, B, C, represent the respective areas of the different portions of the bank.

d, d', d'', the distances of their respective centres of gravity from the centre b,



therefore as A = 55·125 ft. d = 20·75 ft.
B = 66·15 d' = 30·5
C = 62·475 d'' = 11·30

$$g\,b = \frac{55{\cdot}125 \times 20{\cdot}75 + 66{\cdot}15 \times 30{\cdot}5 + 62{\cdot}475 \times 11{\cdot}32}{55{\cdot}125 + 66{\cdot}15 + 62{\cdot}475}$$

$$= 21{\cdot}05$$

The area of the bank = the sum of the areas A, B, C, or 183·75 feet, and the stability of one foot in length of the bank will equal

$$183{\cdot}75 \times 113 \times 21.05$$
$$= 437076 \text{ lbs.}$$

The pressure of the water upon the face of the embankment will equal that of a column of water having the area of the slope for its base, and for its height the column of water above the centre of gravity of the slope; consequently the pressure upon its face will equal that of the prism of water *a*, *c*, *h*, with a right angle at *a*. *a*, *h*, being equal to *e*, *c*, the depth of the water. W, the centre of gravity of this prism, will be the centre of pressure upon the bank; and the force being communicated at right angles to the face of the bank, P, will be the point of application of the pressure = $\frac{1}{3}$ *a*, *c*, and P, *p*. the leverage at which it is applied to overturn the bank on the centre *b*, will consequently = $\frac{1}{3}$ *e*, *c*. As only a portion of the water of the prism exerts a horizontal effort, the amount of such pressure will equal the weight of the prism *a*, *c*, *h*, diminished in the ratio in which the inclined line *a*, *c*, exceeds the depth *e*, *c*; the result being multiplied by $\frac{1}{3}$ *e*, *c*, will give the pressure tending to turn the bank about the centre *b*.

The weight of prism = 4510 lbs. therefore the pressure = $4510 \times \frac{735}{1944} \times 2{\cdot}45$.

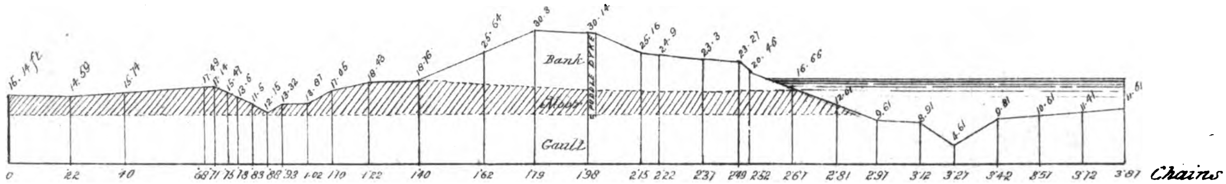
$$= 4177 \text{ lbs.}$$

shewing that the pressure tending to turn the bank about the centre *b* is very much less than the stability of the bank.

The force tending to produce progressive motion will equal the horizontal effort, or

$$4510 \times \frac{735}{1944} = 1705 \text{ lbs.}$$

which is the same as the pressure that would be exerted upon the perpendicular face *e*, *c*, and which is equal to its area multiplied by the distance of its centre of gravity from the surface of the water. The moment of stability of the bank against this force is equal to f (W + P) or the height of the bank



SECTION OF THE HUNDRED FOOT RIVER BANK

SHEWING THE MODE IN WHICH THE FEN BANKS ARE PUDDLED.

B. Latham Del.

and the vertical pressure upon it multiplied by a co-efficient for friction, which in this case will be the friction of quiescence, and may be taken as ·75,

$$W = 183{\cdot}75 \times 113 = 20763$$

and the vertical pressure upon the bank will equal the weight of the prism of water *a*, *c*, *h*, diminish in the ratio of the inclined line *a*, *c*, to the horizontal line *a*, *e*.

$$P = 4510 \times \tfrac{1800}{1943}$$
$$= 4175 \text{ lbs.}$$

which is the same as the pressure exerted by a column of water upon the horizontal line *a*, *e*, whose height is the surface of the water above the centre of gravity of the slope *a*, *c*,

$$\text{then } f\,(W \times P) = {\cdot}75\ (20736 \times 4175)$$
$$= 18703$$

or the effort of the bank to resist the progressive motion, is nearly eleven times greater than the pressure against it. The stability of a bank depends likewise upon the nature of the material of which it is composed and the mode of its construction. If the nature of the material is such as by imbibing water it is rendered semi-fluid, a bank constructed of it will not stand, without special provision is made to make it impervious. It often happens that the only material at command is of itself ill adapted for the formation of a bank; when, to insure its integrity a wall of puddle should be inserted, or the face of the bank may be puddled. This system of puddling the banks was first introduced into the fens by one Smith, of Chatteris, who was a professed embanker. It has the advantage of not only rendering the banks more stable, but by preventing the soakage of water through them into the fens, the great expense of afterwards pumping out the water is saved. In the case of the bank of the Middle Level drain, if not properly puddled, the materials composing it would be better adapted for a filter than a bank; yet it is to be feared that this necessary precaution was never properly carried out, hence its failure. Before the system of puddling the banks was introduced into the fens, breaches were of constant occurrence; and to guard themselves against litigation in the case of the failure of their banks the adventurers had a clause inserted in the Act of Charles II., by which they were liable only to make good the banks with all convenient speed; but owing to the general advance in engineering science, such clauses as these have been rendered unnecessary and would now be thought contemptible.

It has generally been found that where a failure of a bank has taken place it has been the result of the action of the water, either percolating through or overflowing it; in either case the current set up carries away portions of the material composing the bank, which then becomes undermined, and falls, or is broken down by the force of the overflowing water. The success attending the drainage of the fens involves the consideration of the principles upon which the system has been carried out, and which are applicable to many other localities. They are, 1st, That in all works of drainage commencement should be made at the outfall: 2nd, That all rivers liable to floods running through low districts should be embanked; that the two slopes of a bank if produced should make an angle at the top of at least 90°; otherwise the upper portion of such bank is liable to be broken away by the pressure of water, which is always at right angles to the face of the slope; that the banks, if not made of impervious material, should be puddled; and they should be set at a suitable distance from the river, and that the rivers should be straightened and deepened: 3rd, That catchwater drains should be formed which should skirt all the high lands and discharge their waters into the rivers at the lowest possible point. 4th, That low level drains discharging into tidal rivers should be sufficiently capacious for storing the storm waters during the time of high water; that the outfall sluices of such drains should have their cills considerably below low water, if there is sufficient current to keep them clear from silt, &c. These sluices, if built upon semifluid foundations, should be constructed on a suitable platform upon which the superstructure may float, care being taken to equalize the bearing and protect it from being undermined by the water. 5th, That the inclination of the bed of the drains in a flat country may be dispensed with; as the discharge of a drain does not depend so much upon the inclination of the bed as upon the depth of water; as motion, the result of gravity, is greatly accelerated by depth, it will consequently follow that all drains should be as deep as possible, and it will be found that in drains of equal sectional area, working under the same head, the discharge will be greatly in favour of the deeper drain. As an example we have two drains, one 40 feet wide in the bottom and 4 feet deep, with side slopes of 1 to 1; we have likewise another drain of equal area but 8 feet deep; the width of the bottom will be 14 feet if the side slopes are 1 to 1. The area of each drain will be 176 feet, with an inclination of

6 inches per mile, and the quantity discharged by them per minute will equal

$$176 \times 55\sqrt{2 \text{ R H}}$$

in which H is the inclination in feet per mile,

R is the hydraulic mean depth.

In the case of the drain 4 feet deep,

$$\text{R} = \frac{area}{perimeter} - \frac{176}{51\cdot3} = 3\cdot43 \text{ ft.}$$

In the case of the drain 8 feet deep,

$$\text{R} = \frac{area}{perimeter} = \frac{176}{36\cdot62} = 4\cdot82 \text{ ft.}$$

The discharge from the shallow drain will therefore equal

$$176 \times 55\sqrt{2 \times 3\cdot43 \times \cdot5} = 17908 \text{ ft. per minute,}$$

while the discharge from the deeper drain will equal

$$176 \times 55\sqrt{2 \times 4\cdot82 \times \cdot5} = 21199 \text{ ft. per minute,}$$

or eighteen per cent. more than the discharge from the shallow drain of equal sectional area. The drainage of a district is materially affected by the amount of rainfall in that district; in the fens the rainfall is about twenty-two inches per annum; of this but a small portion has to be raised by artificial power into the rivers; in those districts in which the drainage is effected by steam power, upon an average a one horse power engine is found sufficient to effect the drainage of 150 acres.

There are still districts in the fens that have not taken all the advantage they might from the improvement that has been effected in the outfalls during the last few years; and which still make use of steam power to accomplish that work, which could be done by natural means if suitable drains were constructed; there are districts near the sea, or which discharge their waters into tidal rivers that might profitably make use of the great power of the tides to effect the drainage of their fens.

DISCUSSION.

Mr. Muller said he had spent a few days on the works, and could speak with some accuracy as to what he had seen. There was one subject to which he wished to call their attention, which made the great difficulty in closing the drain. It was not the same as in other tidal drains, where there was a

regular ebb and flood. The normal system was perfectly disturbed. The flood in the river Ouse, ran up the Middle Level drain,—in the bank of the drain was a breach, about four miles from the Ouse, the water ebbed out, of course lowering, but as the level of the inundated lands was below the level of high water, the water still ran up the drain, but lowering the level of the water, while it ran down the river Ouse. In fact, there was about nine hours flood in the drain, while there was only six in the river. The remedy he proposed to Mr. Hawkshaw was not to raise up a bank, and raise it up gradually by layers until the water was kept in the fens; but the remedy he proposed was to raise the water by cradles to the same height as the water in the fens, and then to drive piles so that you would only have to contend with four or five feet of water, and there would be no more water in the fens than before.

The reason why the banks were discontinued there, was not because the water was kept up in the fens, but simply as Mr. Hawkshaw mentioned, the fear that one of the boats, or more of them, might break away and run against the piles, and so destroy them. That was the reason against which nobody could object. At the same time being deprived of the boats he could not go on with the bank, and it was then stopped. He was not able now to follow the calculations with regard to the stability of a bank, he had been accustomed to regard the stability from two different views, its resistance to the force of the water at rest, and in motion. The first was the position in which Mr. Latham had calculated the strength of the bank, eminent authorities have found out, and experience had proved that even if a heap of sand was thrown up so that it could stand by its own weight, it would be sufficient to keep the water out, so that sand thrown up so as to stand by its own slope, was sufficient to resist the force of the water when at rest, when the water was in motion it was another matter, then they not only had the weight of the water to keep but the force of the waves running against the slope; the slope, therefore, must be one of the principal features to be taken into consideration with regard to the stability of the bank.

The calculations, as they are made in the paper are very correct when the water is at rest, but I should like to have certain formulæ for the strength of resistance requisite when the water is in motion. He was never able to find one. The principle upon which all banks were constructed was to make them about ten or twenty times the strength that

you thought would be required of them. With regard to the Syphons, the calculation is made with reference to the quantity of water forced through them, with a difference of six feet in the levels. Now the water in the river seldom rose more than fifteen or sixteen feet, while the low water by the bank he made himself, was about six feet. There was a difference of six or seven feet which was only for a few hours. He would like to know whether the calculations were made during the twenty-four hours or during that short time when the water was at a difference of six feet. There was only one perhaps out of the twenty-four hours when there was such a difference.

Mr. E. Reynolds said, that in constructing an embankment in such cases as those before the meeting, it seemed to him quite superfluous to enter into any elaborate calculations of its stability, because it was practically impossible with the usual materials, at their natural slopes, to form an embankment that was not theoretically safe from any risk of failure by overturning; but the tendency to slide horizontally is a very serious matter, and one which could not be met by calculations as to its amount; because it was impossible to define the resistance which any given weight of embankment would oppose to sliding.

He should be glad to learn from Mr. Latham what method was adopted in constructing the embankments in the fens. Was a cutting first made down to the clay, or was the material simply heaped upon the peat. Even if they went down to the clay, it did not necessarily follow, that the bank was secure, for some clay measures were peculiarly treacherous, and liable to slide. Piles might obviate this tendency, but twenty miles of piling would be rather a serious matter.

Mr. Olander said he had one or two observations to make with reference to the cause of accident to the sluice at the entrance to the Middle Level drain. He believed, with Mr. Latham, that it was principally to be attributed to the extra scour on account of the Norfolk estuary works.

As five to six feet fall had been gained by the making of the two mile channel from Lynn seawards to Vinegar Middle, this would to some extent influence the portion of the river where the Middle Level drain discharged itself. Before this cut was made the tides had a circuitous route in the old Lynn channel, whereas afterwards the rate of the tides were considerably increased by the straight cut.

He thought the river had increased its depth since then, and probably

a great deal from St. Germains to the Free Bridge at Lynn. No doubt a quantity of material had been carried away by this increased rate at the entrance of both sluices, viz., the Middle Level sluice and the one nearer Lynn he therefore agreed with Mr. Latham that the accident if not wholly was partially due to the increased rate of the tides.

He agreed with the last speaker that the water in a quiet state would tend to fix the bank, but very different with a heavy wind and sea upon the slope.

With regard to Mr. Muller's cradle dam there could be very little doubt that if it had been raised any height so as to hold up a certain amount of water in the fens, it would have greatly facilitated the works of the coffer dam that was being constructed by Mr. Hawkshaw. There would be a less fall coming out at the head, and the scour would be less, higher up the river.

Mr. Latham in reply said, there was one point that Mr. Muller had brought before the meeting, and that was, the great difficulty of making a dam owing to the length of the time of high water; that being so, the formation of such a dam as Mr. Muller had mentioned could not have mended matters, but, on the other hand, would have greatly extended the inundation: exception had been taken to this view, yet it may clearly be shown that the amount of damage would have been much greater if this dam had been carried up to the height of the water on the inundated lands as proposed by Mr. Muller, for it so happened that the lands under water were circumscribed by a road; this road was vested in the hands of the Marshland Smeeth Commissioners, the Marshland Commissioners were interested in the lands on the opposite side of this road—and as the water was within a few inches of the top of the road it became an object with the Marshland Commissioners to raise it and so prevent the water from flowing upon their lands, but the Marshland Smeeth Commissioners had still some lands which were safe so long as the road was maintained at its present height, as the water must have overflowed it and inundated a very much larger tract of country, before it could have further affected them, so under these circumstances the road was not raised. This being the position of affairs, the formation of a dam that would diminish the sectional area of the waterway, and that too close to the outfall and so prevent the ebb waters passing away, was wisely discontinued; for as certain as it had been constructed, so surely would the water have been

raised upon the inundated lands; because as the water upon the inundated lands was maintained at near a uniform height of eight feet above low water in the river Ouse, which was over three miles distant, the moment a dam was raised in the Middle Level drain close to its outfall into the Ouse, and as high as the water upon the inundated lands, all water that would afterwards flow upon the inundated lands could not be discharged until it had established a sufficient head corresponding to the time of ebb water. It has been said that the formation of this dam would prevent the entrance of the tide; he granted that it would to a certain extent, but inasmuch as it was situated close to the river Ouse, from whence the tides entered the drain, but was over three miles distant from the inundated lands, it would to a greater extent impede the passage of the ebb water, than prevent the entrance of the tides, because the surface of the water when entering and also when passing off the inundated lands may be assumed to be an inclined plane, so that there would consequently be a greater depth of water upon the dam when the tides enter, than when they pass out of the drain, and again when the tides enter the inundated lands they spread themselves over a large area, so that the head that should produce the discharge is diminished.

It may be said that the time of ebb water is greater than that of tide water; this is so, and when the drain was unobstructed it was sufficient, together with the discharge by other sources, to maintain the height of the water upon the inundated lands at near a uniform height; but the very moment a dam is raised above the bed of the drain to the level of the water upon the inundated lands, the inevitable result would be to increase the depth of water upon those lands, and although a uniformity of level would eventually be established, it would be at such a considerably greater height as to have greatly increased the amount of damage.

With regard to the failure of the Middle Level sluice, Mr. Muller gives it as his opinion that the "cause" of the failure was due to the want of sufficient sheet piling; now although sheet piling extending sufficiently far into the banks at either side of the sluice might have rendered the possibility of failure less certain; yet seeing that the failure must be due to some existing cause it could not be attributed to that which was not there, therefore in all likehood the failure was due to the cause mentioned in the paper, viz.; the effects of scour upon a reputed bad foundation.

There was another point that had been referred to, and that was, the effect

of running water upon banks; in the case of a river, with parallel banks which are neither affected by wind or tide, the statical pressure is the greatest pressure those banks have to resist; for this reason, that if the water ran down the river with a velocity due to its head there would be no pressure upon the banks, and where pressure does exist in connection with running water it may be taken as the measure of resistance at that particular point.

The adoption of the six feet head in calculating the discharge from the syphons was purely arbitrary, and was taken to show the relative rate of discharge between them and the destroyed sluice.

In the early history of draining it was the practice to form the banks of the material excavated in cutting the drain; but in a case where there was not sufficient material in the drain, or when the bank was set back a considerable distance from it, an excavation was made a short distance from the site of the bank purposely to get material wherewith to construct it. The earth so excavated was formed into a bank, the weight of which compressed the peat upon which it was laid, and so prevented to a certain extent the soakage. But such banks after a few years could not resist the floods of winter, and until they were puddled were a constant source of anxiety owing to repeated failures, but of late years most of the important banks have been puddled; the mode of executing the work was by digging a trench down into the gault, commencing at the top of the internal slope of the bank; a very few inches of well-worked puddle will make a bank impervious; but in the old banks the puddle dykes vary from 18 inches to 2 feet in thickness, as the whole of the excavation is filled in with the puddle which necessarily could not in a deep cutting be of less dimensions. The water in the fens is kept from two to three feet below the surface of the land, and when it falls below this level, which it does sometimes in the summer months, it is the practice to admit fresh water from the rivers. The general subsidence of the peat has greatly extended the use of the gault to purposes of agriculture, which has thus been brought within easy reach. This system of claying the land is found soon to repay the expense, which varies from 30s. to £3, per acre, and gives employment to a number of men in the winter months who otherwise would be short of work at the very season of the year when it is most needed.

The Chairman said, in his opinion one of the great causes of failure was owing to the bad nature of the bottom, in marshlands generally. He thought

that in many cases the liability to give way would be obviated by piling: if it did not solidify, it would prevent the banks from shifting. By putting in tiers of piles and filling in with hard material and puddle, it would be almost impossible for a bank to be swept away by the action of water or heavy weather. At the last meeting of the Society they had a very interesting history of drainage and reclamation works, many of them of a very ancient character, when the progress of science was less advanced than at present, to go over the whole of that work again would be almost an impossibility, there would, however, from time to time be failures in the different ancient works which would have to be made good, failures against which, due precautions would be taken in all future works.

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